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LONG RANGE SPOIL DISPOSAL STUDY. PART II. SUBSTUDY 1. SHORT RAN--ETC(U)
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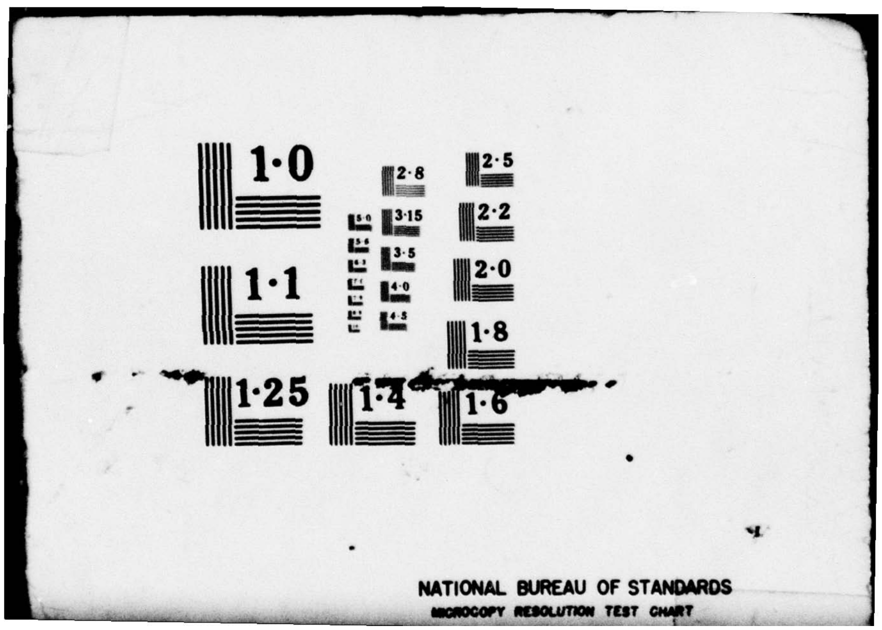
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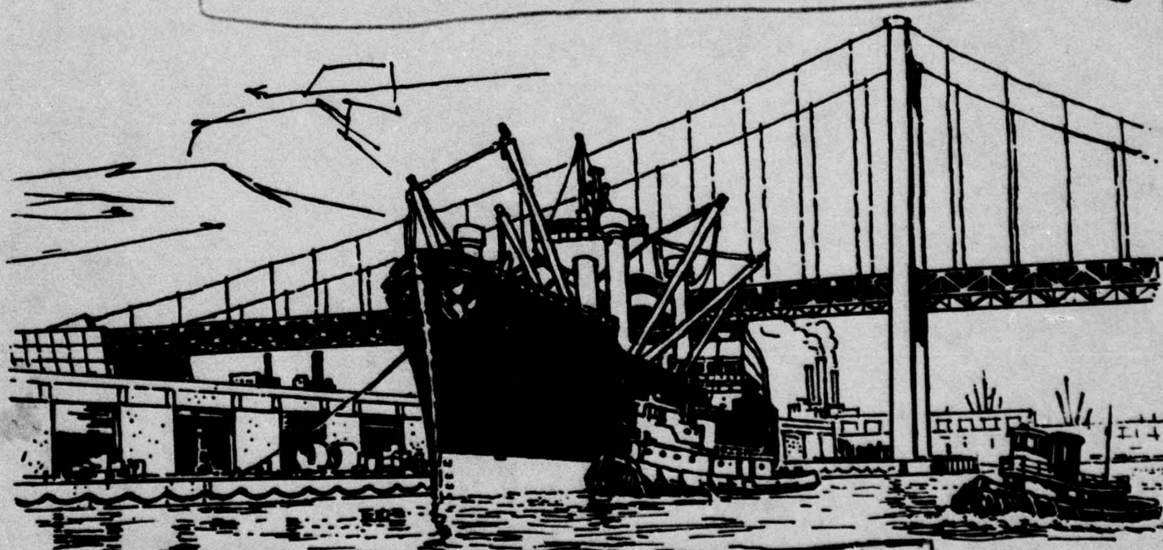
LONG RANGE SPOIL DISPOSAL STUDY.

PART II.

SUBSTUDY 1.

SHORT RANGE SOLUTION.



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FOREWORD

This study and report was completed as one of the six Sub Studies which comprise the overall "Long Range Spoil Disposal Study" in the Delaware River, Philadelphia to the Sea project. The overall study was conceived and initiated in January 1967 by the Philadelphia District Engineer, Colonel W.W. Watkin, who had been directed to such an effort by the Chief of Engineers. The Project Manager for this Sub Study was Mr. Alred A. Hahn, P.E., who had assistance from Mr. Lewis Caccese, P.E.

The study is divided as follows:

PART I - GENERAL DATA ON THE DELAWARE RIVER furnishes the information and data on the Delaware River which is pertinent to the entire study.

PART II - SUB-STUDY 1, SHORT RANGE SOLUTION evaluates the remaining disposal area capacity in terms of its remaining life, and to recommend any further desirable and acceptable disposal area developments.

PART III - SUB-STUDY 2, NATURE, SOURCE, AND CAUSE OF THE SHOAL develops in depth the basic data as to the nature of the Delaware River shoals, their sources, and their causes. It is hoped that this knowledge may reveal new concepts for the better control of shoals.

PART IV - SUB-STUDY 3, DEVELOPMENT OF NEW DREDGING EQUIPMENT AND TECHNIQUE identifies the best in dredging plant and dredging technique for Delaware River dredging maintenance tasks now and in the future.

PART V - SUB-STUDY 4, PUMPING THROUGH LONG LINES examines the merits of transporting dredged materials many miles through pipelines.

PART VI - SUB-STUDY 5, IN-RIVER TRAINING WORK determines the potential of training works for control of shoaling. It involves considerable model testing.

PART VII - SUB-STUDY 6, DELAWARE RIVER ANCHORAGES considers the effect of man-made anchorage on shoaling problems and the merits of alternate solutions.

SUMMARY

This report presents a plan for the disposal area development for the Delaware River, Philadelphia to the Sea project so that maintenance of the Philadelphia Port Area can be continued by the conventional dredging means presently employed. An analysis is made of the relation between future costs for maintaining the Delaware River project channel and the consumption of available disposal areas.

Certain supplementary information regarding Delaware River Disposal Areas has been included as self contained appendix papers. These are: The Consolidation of Dredged Material in Disposal Areas; Disposal Area Diking in Water; and Riparian Sources of Diking Material.

I INTRODUCTION

BACKGROUND

The Delaware River, and particularly the Philadelphia Port Area, constitutes a major port complex. 100,000,000 tons of waterborne commerce move each year through the Port of Philadelphia. This commerce relies, in large part on the man made 40-foot channel; a channel which is constantly subjected to regular shoaling.

The major dredging effort of the Philadelphia District is directed toward maintaining this 40-foot project depth in the Delaware River, see Plate 1. The Port of Philadelphia is 100 miles inland and the Delaware River is constantly seeking to re-establish its natural depth of 17 feet. Maintenance dredging of the Federal navigation project is a continual task which results in the placing of approximately 7,800,000 cubic yards of material ashore each year. This material is dredged to maintain the channel and anchorage depths. The continued availability of acreage to receive this material is the problem. A characteristic of this maintenance dredging is that, for the most part, shoaling, and the subsequent dredging, takes place in repetitive locations and at reasonably predictable rates.

CRITICAL SHOALING AREAS

The most significant shoaling areas are: Marcus Hook, Pa., Philadelphia, Pa., and New Castle, Delaware. These areas represent the majority of the dredging requirements to maintain the Port of Philadelphia. From this it is apparent that any better approaches to the dredging and spoil disposal problems in these areas will have relevance to the dredging work in the entire river.

Since repetitive shoaling occurs primarily at specific locations, disposal areas for the dredged spoil in these vicinities are of key importance. The supply of disposal areas in these critical areas are severely limited because of past use of the most desirable areas and the physical development of the remaining areas. Plate 1 shows the most significant shoaling areas of the river and the related disposal areas.

ANNUAL MAINTENANCE DREDGING

In order to estimate a future average dredging requirement and subsequent disposal area capacity requirement, a study was made to determine the anticipated shoaling rates for the Delaware River. This study reveals that approximately 7,800,000 cubic yards of dredged material are deposited in disposal areas annually to maintain the Delaware River, Philadelphia to the Sea project; of this 1,400,000 cubic yards are from anchorages and the remaining 6,400,000 cubic yards are from the channel itself. Plate 2 represents in graphical form the material removed in maintaining the Delaware River for the past 10 years. The average dredging which has been accomplished during the last five years correlates the data obtained in the shoaling study. The anticipated average annual dredging requirement is also shown in graphical form in Plate 2.

NEW WORK REQUIREMENTS

The disposal area problem has been aggravated by the anchorage improvements authorized by the 1958 modification to the project. The recent enlargement of Marcus Hook Anchorage resulted in the deposition of 18,000,000 cubic yards in nearby disposal areas. The authorized Mantua Creek

Anchorage enlargement, if constructed, will require a disposal area to deposit an additional 15,000,000 cubic yards. There will also be further disposal requirements if work is initiated on two additional anchorages, already authorized in the lower Delaware River, namely Reedy Pt. and Deepwater. There also is an authorized study underway which is considering the need to increase present dimensions of the Delaware River navigation project. Any improvements authorized would require many millions of yards of disposal area capacity.

II PURPOSE OF THIS STUDY

The goal of this study is to locate and obtain, either by fee or easement acquisition, disposal areas which are within economic pumping distance of the dredging requirement. This goal, however, has its limiting factors. Vast land areas along the Delaware River have already been consumed with dredged fill. Marsh and low lands have been filled; many of those remaining have been designated fish and wildlife or water resource areas; see Plate 3. Landowners have been reluctant to enter into long term spoil disposal easements where the filling of their land does not result in land enhancement. Proposed fee acquisition of potential disposal areas has met with intense landowner opposition and opposition from local, county and state officials. The urban Greater Delaware Valley is rapidly expanding and potential disposal areas are being consumed by industrial development. Pressures are also being exerted on the Government for relinquishment of present disposal area holdings so that the real estate may be developed industrially and local tax revenue may become available.

The only large acreage readily discernible for development into disposal areas is in the Delaware Bay regions which is 25 to 50 miles below the repetitive shoaling areas.

III DISPOSAL AREA HISTORY

PAST PRACTICES ON DISPOSAL AREA ACQUISITION

Approximately 862,900,000 cubic yards of material have been dredged by the Federal Government from the Delaware River from 1874 thru 1968 to establish and maintain a navigation channel. Past dredging techniques involving the rehandling of spoil resulted in loss of material which inevitably returned to shoal the channel. (This is discussed in detail in the Philadelphia Engineer District publications "The Sump Rehandling System" and "The Direct Pump Out System." It is also discussed in ASCE paper entitled "Optimum Dredging and Disposal Practices in Estuaries" by Mr. Carl Cable, Assistant Chief, Operations Division, Philadelphia Engineer District, in ASCE Procedures dated October 1967.)

Open rehandling and other dirty

dredging techniques are no longer permitted on Government dredging operations in the Delaware River. To insure positive on-shore retention of all material dredged from the Delaware River, the Philadelphia District has established the policy that all material be deposited in enclosed disposal areas with sluices or weirs to control effluent density and to provide for positive retention of material deposited.

In the past, disposal areas needed for a dredging requirement as a general rule were readily obtained by easement with the landowner. In some instances fee acquisition was employed. However, as the areas in the vicinity of repetitive shoal areas were consumed, and as real estate values rose, fulfilling the requirement for new disposal areas for maintenance dredging by a no-cost easement became impossible. In view of this and in order to avail the Government the return from land enhancement, which frequently occurs from filling of marginal lands, the Philadelphia District Engineer in 1965 proposed fee acquisition of two disposal areas required in order to insure that dredging be accomplished at the most economical cost. These areas were:

The Center Square Disposal Area was proposed for acquisition by Real Estate Design Memorandum No. 1, approved OCE 1 October 1965, to meet the requirement of maintenance dredging in Marcus Hook Anchorage. This area was to provide a capacity for approximately 11,000,000 cubic yards.

The National Steel Disposal Area, formerly Mantua Creek-Woodbury Creek Disposal Area, was proposed for acquisition by Real Estate Design Memorandum No. 3, approved OCE 17 August 1965. This area was intended for the enlargement of Mantua Creek Anchorage and maintenance dredging of the ship channel in this reach of the Delaware River. The National Steel Disposal Area was to provide a capacity in excess of 40,000,000 cubic yards.

The District desired to obtain these areas in order to insure that land enhancement resulting from the fill would revert to the taxpayer, and in recognition of the fact that the person who controls the most logical disposal area for a given dredging requirement can control the dredging. The local contractor who obtains over 80 per cent of the dredging contract awards in the Delaware River has been most astute in controlling disposal areas close to repetitive dredging requirements.

The District program to acquire National Steel and Center Square Disposal Areas met with considerable opposition, much of which was inspired by this local contractor. The landowners of both areas vehemently opposed the Federal Government taking their lands. State and local officials opposed Federal acquisition of land because of the loss in land taxes. Opposition testimony was presented at the Congressional Appropriation Committee hearings. Because of this public resentment, and official opposition, the Philadelphia District Engineer was instructed to abandon the proposed fee acquisition of National Steel and Center Square Disposal Areas.

PRESENT POLICIES

In November 1966, under the direction of a new District Engineer, Colonel W.W. Watkin, Jr., the Philadelphia District reoriented its policy for obtaining disposal areas. It was acknowledged that proposed disposal areas must have maximum public acceptability and the right of the Government to use "eminent domain" would not be relied on. This necessitates obtaining areas by other than fee acquisition. All

factors are taken into consideration which pertain to the effect of the disposal area on the total environment of the region. These factors include the effect of the disposal area on fish and wildlife; on water pollution; on esturine ecology; on recreation; on natural beauty and scenery and on the economies and planning of the local community. The selection of a proposed disposal area must also be coordinated with local and regional planning commissions. Today, the Philadelphia District brings a whole array of voices and interests into disposal area planning and determination.

NAVIGATION SERVITUDE (See Footnote)

In discussing disposal areas it is valuable that there is a full appreciation of the import of "Navigation Servitude"; the right it gives to the Government to take riparian land for disposal area use without compensation; and the limits to which those powers are exercised in the acquisition of disposal areas.

The Supreme Court typically refers to the navigation servitude as a "dominant right", a "right of plenary nature", a "superior power". The navigation servitude is a shorthand expression for the rule that in the exercise of the navigation power certain property rights may be taken without compensation.

"Navigation Servitude" gives the Government the rights to use any part of the bed of a navigable river or its tributaries in the interest of navigation. This right includes creating disposal areas in the bed of a stream for the spoil from dredgings. The bed of a stream is defined as extending to the "ordinary high water" mark. A man made change to the high water mark by the deposit of fill below high water, or any other man made construction, has no literal significance in the application of navigation servitude. In short that area which nature intended to be below the high water line always continues to be available for the benefit of navigation and subject to navigation servitude. The benefit of navigation may be in the form of a new channel, an improved channel or a spoil disposal area. From this it follows that dredged spoil can be placed in riparian areas, to unlimited heights, despite any previous improvements man or the riparian owner may have made thereon, without any consideration or compensation to the riparian owner. The only condition on such a use of navigation servitude would be the fact that navigation is being truly served and that the taking is reasonable and not arbitrary.

The doctrine of "Navigation Servitude" flows from the commerce clauses in the Constitution. The doctrine has a uniqueness that makes it difficult for the uninitiated to comprehend; for it seems to be a taking of property without just compensation, which is in violation of the 5th Amendment. The rational which controverts this seeming inconsistency with the 5th Amendment is a notice theory: All who make use of navigable waterways or riparian sands "know" or "should know" that any right which they acquired were always subject to the prior rights of navigation that is subject to navigation servitude.

In actual practice in the Philadelphia District the taking of fast land which has been created on riparian land in the interest of navigation rarely occurs. The most notable such exception was the taking of bulkheaded lands and buildings thereon without compensation from Mr. George

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Reference: Water and Water Rights Vol. II; Editor Robert Emmett Clark; Publisher: The Allan Smith Company.

Schaffer at Chesapeake City along the Chesapeake and Delaware Canal in 1967. This incident involved taking a store and restaurant property which had been developed on filled land below the "ordinary high water mark." The property taken without compensation was valued in the many thousands of dollars.

MARSH LANDS

The most frequent consideration in connection with the use of navigation servitude is for the use, as disposal areas, of the marsh land adjacent to the Delaware River and Delaware Bay and marsh land adjacent to the tributaries of the Delaware River. There continue to exist approximately 175,000 acres of such marsh land. The use of such land for spoil disposal presently meets with strong opposition from diverse interests. Conservationists desire to preserve marshes in their natural state (See Plate 3); others utilize them for receipt of refuse and trash; local governments desire that marsh land be privately filled and developed and industrialized to increase tax revenues. These forces are sufficient so that, for the most part, the development of marsh lands for spoil disposal purposes are only undertaken with the written assent of the owner in the form of a spoil disposal easement and the assent of other interests; and the plenary powers of navigation servitude are not utilized. The use of a marsh land for spoil disposal is forfeited rather than entering a conflict with other interests. In view of this, navigation servitude becomes of little value in spoil disposal planning on marsh lands.

RIVER BED

The navigation servitude exists not only over the marsh land but it extends over the entire river bottom. Here again the practicalities of society, rather than any limitations of law, limit the exercise of this right on the river bottom. Any proposed riparian disposal area developments are only approached after the feelings of upland owners, the views of the state, and the views of the riparian owner are considered and accommodated. The limitations these interests impose are severe. For example, the State of Delaware is in a unique position where its border with the State of New Jersey is at the low water mark on the New Jersey side of the Delaware River between Claymount, Delaware and Port Penn, Delaware. The riparian areas on the New Jersey side of the river in the vicinity of Pedricktown, N.J., have appeared as a desirable site for disposal area development. Such a development has not been pursued since it violated the desire of the State of Delaware. Delaware, with considerable merit, opposed the creation of any fast land by spoil disposal of the Jersey side of the river since it would become the responsibility of Delaware.

EXISTING DISPOSAL AREAS

As seen on the map, Plate 1, there are presently seven Government-owned disposal areas in active use for the maintenance dredging requirement of the Delaware River, Philadelphia to the Sea project.

Artificial Island Disposal Area has the greatest potential capacity, however, it is located 25 miles below the critical shoaling region at Marcus Hook. Obviously the critical areas are where the shoaling rates are the most severe and the disposal area potential is smallest. The Marcus Hook Area and the Mifflin Range Area are most characteristic of the critical shoaling problems.

LOSS OF DISPOSAL AREA FOR OTHER LAND USE

Exchange of Land with the Public Service Electric and Gas Company:

The Philadelphia District has obtained fee title to 137 acres of land formerly owned by the Public Service Electric and Gas Company. The circumstances behind this acquisition merit discussion. In September 1967 this District was informed by the Public Service Electric and Gas Company that the Government owned Artificial Island Disposal Area was a highly desirable site for a proposed nuclear powered electrical generating station. Subsequent discussions with Public Service revealed that a transfer of land could be accomplished which would be mutually beneficial to both parties. This District released a portion of Artificial Island Disposal Area in exchange for a parcel of Public Service land located along the critical shoaling region of the Delaware River at National Park, New Jersey.

Appendix A contains a tabulation of statistics and cost evaluation for the areas effected by this transfer. This tabulation reveals a loss to the Government in net disposal capacity. However, the capacity gained at National Park has greater real value than the capacity lost at Artificial Island because of its geographical location along the river. The National Park Disposal Area is located along a critical shoaling region of the Delaware River and is so located as to enable its utilization by both the hopper dredges maintaining the 40-foot ship channel and the contractor pipe line dredges maintaining Mantua Creek Anchorage. When all disposal areas have been consumed along the critical shoaling region of the Delaware River, maintenance dredging costs will more than double. (This conclusion is based upon continued use of present day dredging techniques). It has been estimated the disposal area capacity at National Park is ultimately worth approximately $4,875,000 to the Government in savings in dredging costs.

Artificial Island - Alloway Creek Disposal Area was inaccessible by land. All construction equipment and personnel required to maintain and develop this disposal area had to be brought in by barge and boat. The agreement for the exchange of land gives the Government the right to use the access road constructed by Public Service for egress and ingress to the remaining disposal area at Artificial Island. This results in savings to the Government in both transportation costs for equipment and personnel in addition to a saving in time required to transport equipment and personnel to Artificial Island.

The Public Service Gas and Electric Company will provide necessary diking around their plant area on Artificial Island to compensate for the Government's investment in the peripheral diking in the 200 acre area being released.

The exchange of land with the Public Service Electric and Gas Company is one example of the loss of a portion of an existing Government-owned disposal area. In this instance, the loss of land was offset by the acquisition of comparable lands. It is apparent that there will be increasing similar demands in the future for Government-owned disposal area lands for projects which result from the growth of the area and which would result in an overwhelming economic benefit. For example, the remaining 3500 acres of disposal area at Artificial Island provide a highly desirable industrial site because of its proximity to the proposed nuclear powered electric generating plant. This is especially true for a high power demand industry.

The State of New Jersey has already made such inquiries regarding the availability of this area. It is believed that disposal areas will not be retained for dredge spoil whenever it is shown that the area is required for a project of considerable public benefit.

Existing Government-owned disposal areas are subject to encroachment by the rapid urban development of land in the Delaware Valley. The existing disposal areas may someday be the only remaining land areas suitable for development by a large industry requiring marine facilities. In addition, regional planning commissions and port development organizations always eye the disposal areas for future marine terminals and similar facilities. Instances of encroachments exist in the recent past. An increasing demand can be expected. The past examples are loss of 70 acres of Government-owned lands to Fish and Wildlife interests in Darby Creek; the loss of the Darby Creek Disposal Area to accommodate construction of the Delaware Expressway; elimination of Government-owned disposal area acreage on the Schuylkill River to accommodate a new bridge structure; transfer of Government-owned lands to the local community at Killcohook for road construction purposes as well as the release of acreage at Artificial Island for construction of a nuclear power plant. These were all merited transactions in the best public interest. Others of similar nature will likely continue at an accelerating rate in the years to come.

SEARCH FOR POTENTIAL DISPOSAL AREAS

In September 1966, in implementation of the program to obtain disposal areas by easement agreement, negotiations were undertaken with all landowners of potential disposal areas. In addition, letters were written to users of large quantities of fill material, such as highway departments and, because construction of a new jet runway was imminent, the Philadelphia International Airport. The campaign to obtain buyers for Delaware River spoil material was fruitless.

The potential disposal areas which were determined for various reasons as non-available for development are shown on Map, Plate 4. Most of the areas were eliminated by decisions of the landowner. This *negative response is attributed to:*

1. Landowner does not benefit from the filling of his land because the area is presently suitable for development.

2. Delaware River maintenance spoil is not always desirable land fill material because of its high silt content. (See Appendix E).

3. Landowners do not desire to have their land dormant for the long period of time necessary to fill the area with normal anticipated annual maintenance dredging.

There are other factors besides landowner objection which necessitated elimination of potential disposal areas from the list of those considered for development. The circumstances which led to the elimination of a potential disposal area in the Borough of Folcroft, Pa., merits discussion. The potential Folcroft Disposal Area is located on marsh lands along Darby Creek opposite to the existing Darby Creek Disposal Area. The major landowner of this area had contacted the Philadelphia District and asked that the Corps consider using his lands for deposition of hydraulic spoil. The Borough of Folcroft, also a landowner of a portion of the potential disposal area, agreed to provide an easement to permit the filling of borough land. The Borough officials sup-

ported the filling of this marsh land. However, the marsh land along Darby Creek has been designated as a key fish and wildlife area. Proposed filling of these marsh lands resulted in opposition from fish and wildlife interests. In view of this, the Folcroft area was not considered as a potential area for development.

AREAS SELECTED FOR DEVELOPMENT

In view of the foregoing, it was concluded that efforts in obtaining new areas should be directed primarily toward developing disposal areas in riparian lands in the river. Although costly to develop, a riparian disposal area would have least objection from the varied interests, since new land is being created. In addition, "Navigation Servitude" applies.

The study of potential riparian disposal areas concludes that the most promising areas for development are: Goose Island Disposal Area, Tinicum Disposal Area, and Chester-Monds Island Disposal Area. These three riparian areas are delineated on Plate 4. Appendices B, C, and D contain discussions and engineering data on each of these areas. The Goose Island Area is valuable because of its proximity to the major shoaling area at Marcus Hook and its potential capacity of approximately 13 million cubic yards. The attributes of the Chester-Monds Island area are its potential capacity of approximately 37 million cubic yards; the fact that it is located between the two major shoals at Marcus Hook Range and at Mifflin Range; and the fact that it would ultimately produce a large parcel of new land in an area of the Delaware River where further development may be a particular asset. The Tinicum area can be an important development because of its potential capacity of 26 million cubic yards and since it is the last large disposal area development which may be possible in the vicinity of Philadelphia Harbor.

IV DISPOSAL AREA POTENTIAL

FILL ELEVATION

The criterion of a maximum fill elevation of 25 feet, which professional real estate operators have found to be most beneficial, has been adopted by the Government for the most part in their disposal area development. The numerous objections to the acquisition of further real estate for disposal area use, required a reevaluation of the former position on the heights to which disposal areas will be developed, in order to maximize their potential. It should be noted that a maximum elevation of 25 feet necessarily results in a lower average elevation. Dredged fills even with light material take on an appreciable slope. A 10-foot drop from one side of a disposal area to the other is not uncommon. Further limitations on heights of fill are encountered by the strength of underlying materials, adjacent drainage problems, and other local considerations. Experience in the last decade has revealed that local physical conditions of varying natures frequently limit elevations to 20 feet, and less, in some portions of a disposal area.

For example, 17 feet of fill was the maximum attainable along Raccoon Creek due to weak subsurface conditions. A 20-foot limit was encountered on the Route

130 side of the Raccoon Creek Area because of displacement of the bottom of the highway drainage ditch. Limiting elevations of 20 feet were required on the Delaware River Side of the Pigeon Point Disposal Area because of limited foundation strength. Limiting elevations of 25 feet were required on considerable acreage at Killcohook Disposal Area because of a raising of the water table due to the filling with attendant damage to adjacent cemetery property. A 30-foot elevation of fill caused a serious sub surface failure at the Government-owned Edgemoor Disposal area in 1967 with considerable resulting damage to an adjacent sewage disposal plant and railroad.

There are instances along the Delaware River, most notably at the Killcohook Disposal Area, where fill has reached 40 feet in heights in areas along the river front. Generally, this has been accomplished by stepping in or encroaching into the disposal area with successive lifts as the banks are raised. The 40-foot high bank is not abortive of the aesthetic value of the areas particularly when the height is attained by stepping in banks. The 40-foot height achieved on these banks are in the portion of the disposal area where the dredge pipeline discharges are located and the coarser materials settle. The finer particles which are carried further distances to the outer end of the disposal area do not provide the suitable material required for 40-foot high banks.

Another factor which bears on the height of fill or capacity of the overall area is that fills take significant slopes from the point of pipe discharge towards the sluice. So a given elevation at one end of a disposal area will result in a lesser elevation elsewhere in the area since it is usually not practical to reach all portions of the disposal areas with the pipe discharge.

In summary, it is adjudged appropriate that, as a general rule, an average elevation of 30 feet in Government-owned disposal areas is the realistic maximum planning elevation for the future. This recognizes that an elevation of 40 feet can be attained in some locations while 20-foot elevations will likely be the limiting elevation at other locations. In evaluating disposal area capacity it is recognized that since light weight shoals are involved, and since areas are subject to intermittent filling because of repetitive dredging, that every three cubic yards of dredged material will only consume two cubic yards of disposal area capacity due to the consolidation of the materials. These judgments are used in this report.

POTENTIAL OF PRESENT DISPOSAL AREAS

Considering the foregoing criteria the estimated remaining capacity in Government-owned disposal areas as of the end of FY-68 was:

Name	Acreage	Gross Capacity (C.Y.)	Net Capacity (C.Y.)*
National Park	154	6,500,000	9,750,000
Darby Creek	196	3,000,000	4,500,000
Pedricktown	1215	26,760,000	40,140,000
Penns Grove	290	7,360,000	11,040,000
Penns Neck	347	6,400,000	9,600,000
Killcohook	1200	23,300,000	34,950,000

*Dredged cubic yards

Assuming normal anticipated consumption rates, the remaining potential of these areas are illustrated on Figure 1. This figure illustrates that physical disposal area capacity remains until 1986. It has been assumed that 1,000,000 c.y. of the annual dredging requirement is deposited in private or contractor controlled disposal areas. A cost increase of 30 per cent occurs in 1984; see Figure 4. In 1985 dredging costs more than double present day prices, and in 1986, when all upriver disposal area capacity is exhausted, annual dredging costs increase by $6,400,000 for the Delaware River, Philadelphia to the Sea project. These cost rises are those which come about only because of longer haul requirements after consumption of existing nearby disposal areas; all these costs are computed on 1968 cost levels.

POTENTIAL OF NEW DISPOSAL AREAS

The potential new disposal areas are:

Name	Acreage	Gross Capacity (C.Y.)	Net Capacity (C.Y.)
Goose Island	374	13,000,000	19,500,000
Chester-Monds Is.	835	37,300,000	55,950,000
Tinicum	400	26,500,000	39,750,000

Figure 2 illustrates the pattern which would result if the Tinicum, Chester-Monds Island, and the Goose Island areas were all developed to maximum capacity. Total capacity would remain until year 2006 and no significant rise in dredging cost would take place until 1988. A saving in dredging costs amounting to $108,840,000 would be realized between the year 1984 and 2006 if all three of the potential areas were developed.

REALISTIC POTENTIAL FOR PLANNING

The foregoing analysis based on the Government not acquiring any new areas is considered to be too conservative to be realistic while the analysis based on the full development of the Tinicum, Chester-Monds Island and the Goose Island areas is considered too optimistic to be realistic.

It is considered that the most realistic assumptions and those which should be used for planning purposes are:

1. 10 per cent of the present remaining capacity of the Government-owned areas will be lost in response to the increasing demands for return of Government acreage to accommodate specific requirements.

2. Only 66 per cent of the Chester-Monds Island potential can be filled before the area is lost due to other essential land use requirements.

3. The development of the Goose Island Disposal Area will not take place because of severe criteria imposed by *Monsanto*.

4. The potential of the Tinicum Disposal Area will not be realized. Problems will arise in obtaining the land from the present owners; the reluctance of some of the local interests to endorse the project; limitations on height of fill imposed by local interests; and in response to local desires to have property returned for development as rapidly as possible.

These conclusions are transposed into the most realistic predictions of the future, which are assumed for planning purposes. These are shown on Figure 3. This figure reveals disposal area capacity will remain until 1990. Figure 4 reflects a

significant cost rise of 30 per cent taking place in 1987.

NEW WORK DREDGING REQUIREMENT

There are presently two proposed and authorized project improvements which have critical disposal area requirements. The proposed enlargement and deepening of Mantua Creek Anchorage will require approximately 14,400,000 cubic yards of disposal area capacity. The development of a new anchorage at Deepwater Point will require disposal of approximately 5,560,000 cubic yards of dredged material. Following is a discussion of each requirement:

Mantua Creek Anchorage

The most logical disposal area for the deposition of dredged spoil from the enlargement of Mantua Creek Anchorage is the 1900 acre National Steel property located immediately behind the anchorage in Gloucester County, New Jersey. This property was proposed for fee acquisition in 1965. Because of considerable public opposition, however, plans were abandoned to acquire this area in fee.

In August 1966 negotiations with National Steel were started for the purpose of obtaining a spoil disposal easement for their lands behind Mantua Creek Anchorage. On 14 July 1967, after a year of discussions, the Philadelphia District was successful in obtaining a five year spoil disposal easement with the National Steel Corporation.

Start of work for the enlargement of Mantua Creek Anchorage has been deferred. It is not anticipated that the National Steel Corporation will grant an extension to the present easement or grant a new easement after 1972. The National Steel Corporation has been most skeptical of the quality of fill to be deposited upon their lands. The material that will be dredged in enlarging the anchorage will meet National Steels' criteria; subsequent maintenance dredging material will not.

Deepwater Point Anchorage

The original area designated for disposal of the new work dredging requirement of approximately 5,560,000 cubic yards, was Helm Cove located near Carneys Point, New Jersey. In negotiations with the upland owner, E.I. Du Pont de Nemours & Company, it was discovered that certain development restrictions would have to be imposed on the proposed Helm Cove Disposal Area to insure that the Du Pont Carneys Point Plant operation would not be affected by the disposal area development. These restrictions resulted in limiting the capacity of the Helm Cove area to only 2,500,000 cubic yards, and rendered this area unsuitable for the dredging requirement.

In May 1965, the Philadelphia District proposed to acquire in fee a 460 acre plot of land owned by the Lukens Steel Company in New Castle County, Delaware, for the Deepwater Point Anchorage dredging requirement. The Lukens Steel Company opposed the fee acquisition of their lands. Because of the public opposition caused by the proposed fee acquisition of the Center Square and National Steel Disposal Areas, plans to acquire the Luken's property in fee were abandoned in 1966.

Since February 1967 the Philadelphia District has been attempting to negotiate a spoil disposal easement with the Lukens Steel Company for their lands in New Castle, Delaware. These negotia-

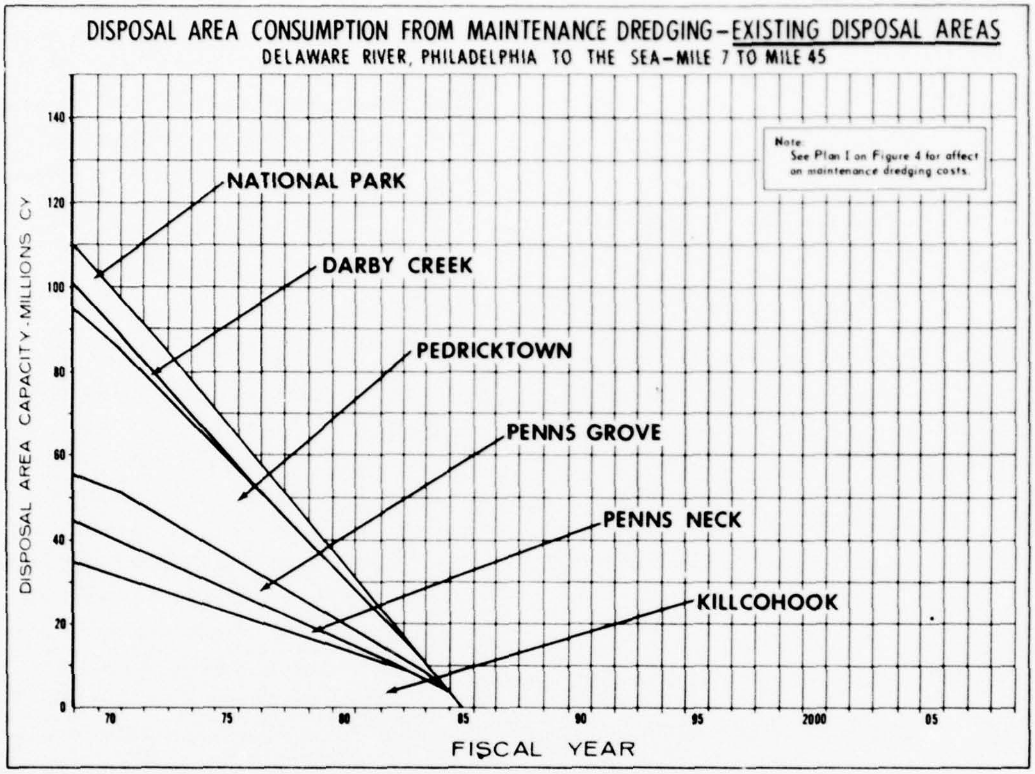

Figure 1

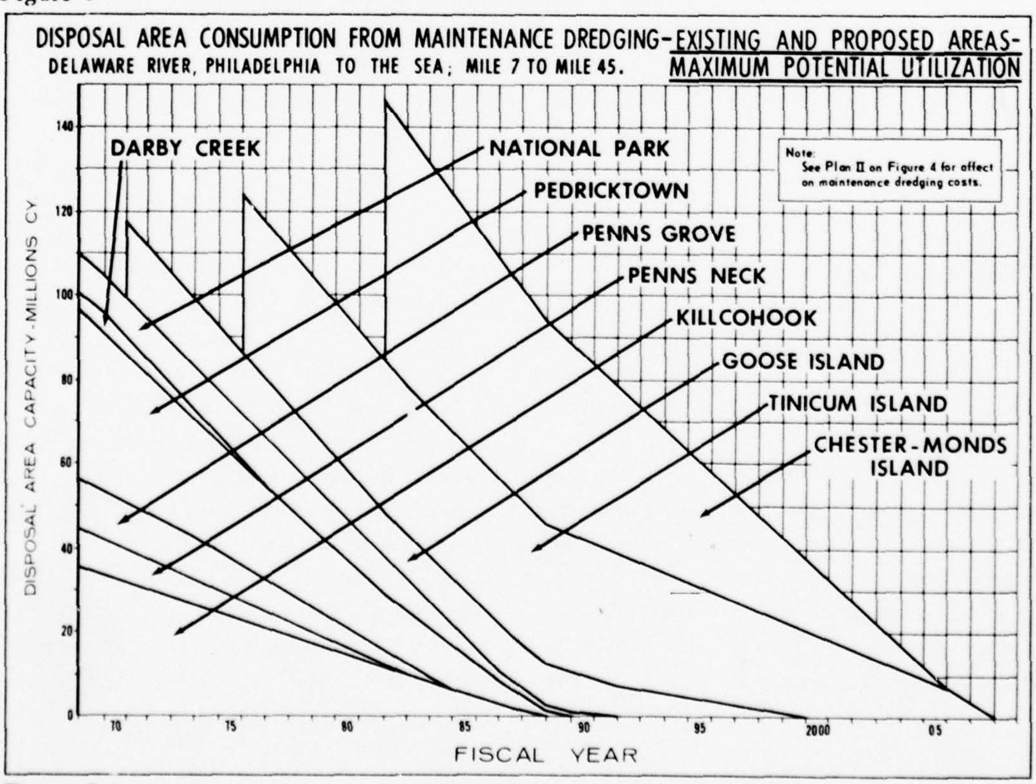

Figure 2

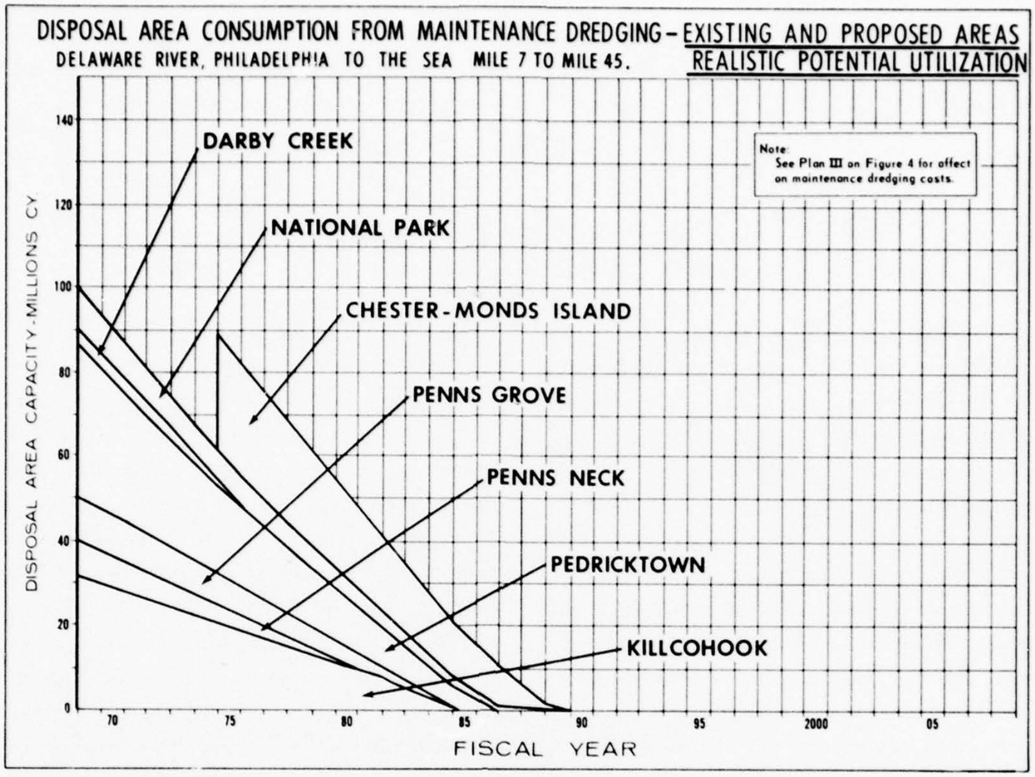

Figure 3

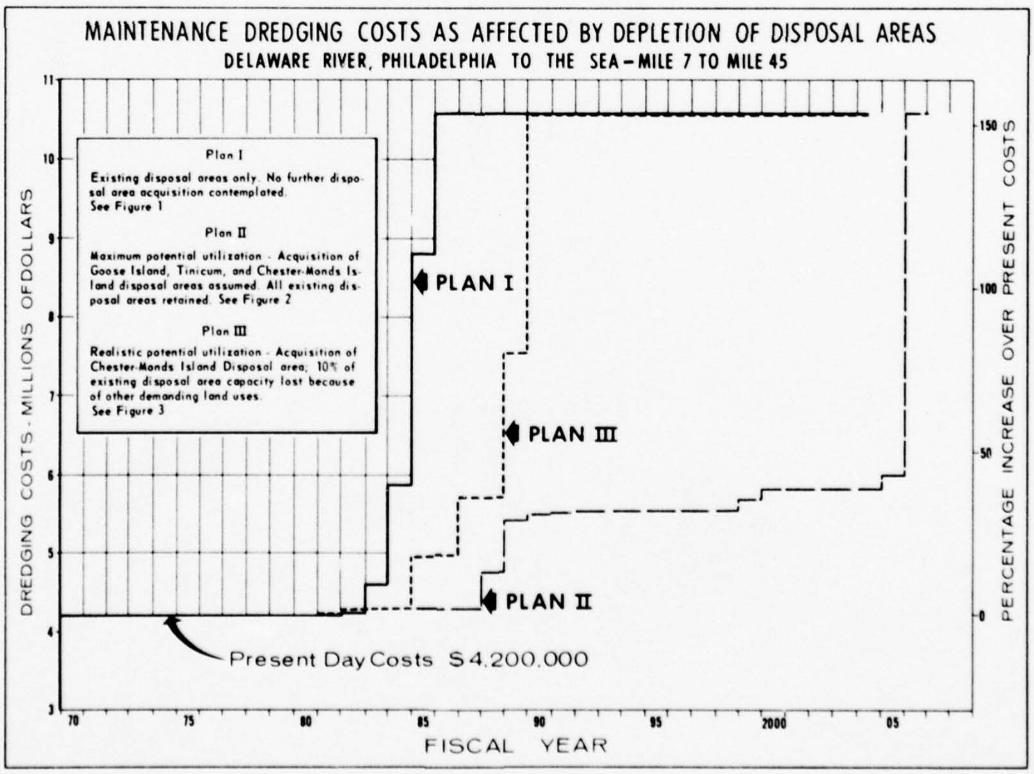

Figure 4

tions have failed. Lukens officials have concluded that use of their lands for disposal of dredged material will result in an overall devaluation of the property.

V CONCLUSIONS

This report concludes that the maintenance of the present navigation improvements in the Delaware River, Philadelphia to the Sea project, can continue using current maintenance dredging techniques without any significant increase in cost attributed to consumption of disposal area capacity until 1988. At this date, a 30 per cent price rise will occur, due to the consumption of all disposal areas above Chester, Pa. It is also concluded, within the limits of our present vision, maintenance of the Delaware River channel from the Sea to Philadelphia should be possible by present day approaches until 1990.

It is evident that spoil disposal areas are limited in the Delaware River and that any significant channel or anchorage improvement which might hereafter be undertaken should have its dredged spoil deposited in areas other than those which are identified in this report as maintenance spoil areas. To do otherwise might accelerate depreciation of the port rather than providing an improvement by the fact that it would be utilizing irreplaceable maintenance capacity. In this connection past projects, such as anchorage improvements, which were costed and approved on assumptions of readily available disposal areas, should be reconsidered prior to undertaking work. In this category would fall the proposed enlargement of Mantua Creek Anchorage and the proposed Deepwater Anchorage.

APPENDIX A

EXCHANGE OF LANDS
WITH PUBLIC SERVICE

I. *DISPOSAL AREA STATISTICS*		
A. Artificial Island Disposal Area		
Acreage		
U.S. Fee		2,694.75 Ac ±
Existing Disposal Area		3,872.00 Ac ±*
Disposal Area Statistics		
Present Capacity	101,900,000 CY	
Estimated Development Cost	$0.05/CY	
Effect of Transfer		
Capacity Lost	12,160,000 CY	
Acreage Lost in Fee	200.00	
Remaining Capacity	89,740,000	
B. National Park Disposal Area		
Acreage		
To be Obtained in Fee		134.70 Ac ±
Disposal Area Acreage		
Fee Area Plus Riparian Lands in Woodbury Creek		137 Ac ±
Public Service Easement		17 Ac ±
Disposal Area Statistics		
Capacity of 154 Acres to +25'	6,500,000 CY	
Estimated Development Cost	$0.11/CY	

*Includes approximately 1,300 acres of New Jersey riparian lands.

II. *ECONOMIC JUSTIFICATION FROM DREDGING STANDPOINT*		
	LOSS	*GAIN*
A. Artificial Island Disposal Area		
Value of capacity lost at Artificial Island 12,160,000 CY @ \$0.05/CY development cost	= \$ 608,000	
Value of fill to Public Service Company 2,000,000 CY @ \$0.10/CY	= 200,000	
Access to Disposal Area		Intangible
B. National Park Disposal Area		
Development cost - 6,500,000 CY @ \$0.11/CY	= 715,000	
Saving in dredging cost - 6,500,000 CY @ \$0.75	=	\$4,875,000
TOTAL	\$1,523,000	\$3,901,000
NET		+\$3,352,000

APPENDIX B

GOOSE ISLAND DISPOSAL AREA

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PURPOSE

The Goose Island Disposal Area is located in the reach of the Delaware River where maximum shoaling is known to occur. This proposed disposal area will accommodate dredging from both Marcus Hook Anchorage and the Marcus Hook Range of the 40-foot channel.

LOCATION

The proposed disposal area is located along the New Jersey-Delaware River shoreline at the confluence of Raccoon Creek. It is located approximately two miles west of Bridgeport, New Jersey; see Plate 5.

OWNERSHIP

The disposal area site consists of both a riparian area in the bed of the Delaware River and fast land. The fast land is the property of the Monsanto Chemical Company. The riparian area is within the boundaries of and owned by the State of New Jersey. The Monsanto Company desires to acquire the state-owned riparian lands which will ultimately be developed by the proposed disposal area.

HISTORY

The upland area and fast land presently owned by the Monsanto Company has been used in the past for disposal of hydraulic fill. The present site of the Monsanto Chemical plant was filled many years ago by a private dredging company. Approximately 200 acres of Monsanto Company land were filled in 1965 by the Bauer Dredging Company in conjunction with the enlargement and deepening of Marcus Hook Anchorage.

ACCEPTANCE

In order to gain the maximum acceptability to the proposed Goose Island Disposal Area, the Philadelphia District has met with State and local officials, and the upland owner, the Monsanto Company. State and local officials have been most amenable to the planned development of the riparian land. The Monsanto Company's initial reaction to the development of the riparian land was not favorable. In subsequent discussions, however, Monsanto concurred to the proposed disposal area provided certain conditions are accomplished:

1. Monsanto buy the riparian land and establish criteria regarding its development.
2. Certain other Monsanto lands be filled.
3. The Corps of Engineers insure that upland drainage would not be affected by the proposed disposal area.
4. The Corps of Engineers provide a cleaning of Birch Creek between the Pennsylvania Railroad and the Delaware River.
5. A suitable spoil disposal agreement be executed containing all the above conditions.

The requirements imposed by the Monsanto Company were not acceptable to the Government. The acceptance, in writing, of limitation pertaining to the paramount rights of the Government to utilize riparian lands may have implications Corps-wide. A mutually satisfactory agreement is, therefore, not attainable at this time. In view of this, there are no current plans to develop this area in the near future.

ENGINEERING CONSIDERATIONS

Subsurface Explorations and Testing

The subsurface explorations for the preliminary design of the disposal area diking were performed during May and June

1967. The main exploratory effort was performed in the area of Stage 1 development adjacent to Goose Island (as shown on Plate 5). Several borings were made to determine borrow conditions in the area downstream of Birch Creek.

The explorations were made by the wash boring and "dry" sampling method using 4-inch diameter casing. Sampling included both drive and undisturbed sampling. Drive samples were taken with 2-inch and 3-inch diameter split spoon samplers and undisturbed samples were taken in selected borings using a 3-inch diameter stationary piston sampler. In addition to the sampling program 3-inch diameter vane shear tests were made to determine the insitu strengths of the cohesive materials encountered along the proposed dike alignment.

Plate 6 shows the final depths of the borings, the numbers of undisturbed samples taken and the vane shear tests performed.

The contractor employed four different modes of drilling equipment transport and/or mountings. For holes drilled on the Delaware River, the rig was mounted on a large metal barge because of the rough water that is common in the area and the depth of water at some boring locations. In Birch Creek, a barrel float was used to transport a skid rig. The rig was unloaded from this barge and moved onto each hole location. This method of transport was chosen by the contractor due to existing surface conditions.

A skid rig and a rig mounted on a power wagon were used in the land areas. Each rig was used as site conditions dictated. The drill rigs used were of standard design (similar to S & II 40c & 142) and were required to have a hydraulic system capable of pushing 30" long x 3" diameter stationary piston samplers to 2 feet penetration in one continuous stroke.

Subsurface Conditions

Foundati conditions along the proposed dike alignment range from fair to poor. The most favorable foundation condition is found in the segment from Station 5+340 to Station 10+850. In this section, the foundation materials generally consist of a top layer of silty sand and clean sand underlain by stiff organic silts. The materials along this portion of the dike alignment are generally from medium to dense and are considered fair to good foundation for dike construction. Along remaining portions of the alignment, foundation materials are composed of soft to very soft organic silts and clays extending to a depth of at least 10 feet below the ground surface. This foundation is considered to be poor for dike construction and will require a substantial dike section for stability.

Two borrow areas were located in the vicinity of the proposed disposal area. These are shown on Plate 5 and are designated Borrow Areas 1 and 2. Borrow Area 1 is predominantly composed of sands and silty sands containing an average of approximately 25% fines and extending from the ground surface to an average depth of approximately 35 feet below ground surface.

Borrow Area 2 consists predominantly of clean sands with very little fines. This material extends from the ground surface to an average depth of 30 feet below ground level. Average elevation in this area is +14 and the average elevation of the GWL at the time of the explorations was +8.5.

Dike Design

The general dike alignment proposed in the preliminary design is shown on Plate 5 and follows recommendations made by the Hydraulics Branch for that portion of the dike in the Delaware River.

The alignment indicated on Plate 5 shows the centerline of the dike to be approximately 900' from the 40' depth of the enlarged Marcus Hook Anchorage, whereas the preliminary study plan locates the toe of dike at approximately 400' from the 40' depth. This alignment was modified to a greater distance from the anchorage due to the lack of sufficient survey data available in the vicinity of the dike area. Additional bottom surveys must be made before the final design is initiated. Based on this additional survey information and more complete design analysis, it is believed that the dike alignment would be at a distance considerably closer to the anchorage limits.

Should it be decided that a dike is not to be built along Birch Creek, a dike would then be built from Station 10+850 to the existing dike of Monsanto Disposal Area. The "B" dike section is adequate for this segment of the dike.

The design presented herein is based upon the assumption of staged construction and calls for two dike sections. The section employing an initial stage with 3:1 side slopes and a top width of 15 feet at elevation +12 feet is for that portion of the dike from Station 0+000 to Station 5+340 as shown on Plate 5 as dike section "A". The rest of the dike employs a dike section with 5:1 side slopes, 15 foot top width at elevation +12 feet, and is shown as dike section "B".

An average allowance of 5 feet has been provided for consolidation and/or displacement of foundation material during the first stage of construction for Dike "A" and 1 foot for Dike "B".

The raising of the dikes above the elevation +12 feet will be made with a series of incremental dikes to a final top elevation of +27 feet. This method is based upon the use of materials immediately adjacent to the dikes on the inside of the disposal area as a borrow source for the incremental diking. This design assumes that the discharge of dredged materials being pumped into the disposal area will be along the perimeter of the inside of the dike. In addition to providing a solid base of granular materials for the incremental diking, this method of discharge provides good diking material next to the dike. The typical dike sections are shown on Plate 6 with the soil profiles along the dike alignment.

Riprap will be placed on Dike "A" from Station 2+710 to 5+340. It will also be placed on Dike "B" if excessive erosion of the 5:1 outer slopes occur during or after construction.

The dike section designs were determined by use of the Swedish Arc method of slope stability. The cases investigated were the as-constructed and steady seepage cases. Design strengths for foundation materials were based upon vane shear tests performed during the explorations. The adopted design values are shown on Plate 6.

Although a safety factor of 1.20 is the minimum allowable for this design, Dike "A" had a safety factor of 1.08 in the steady seepage case. It was the only computed value below 1.20 and, since no other test data was available at the time of this preliminary design, it was assumed that the consolidation of the foundation material under embankment loading would increase its strength and the 1.08 would increase to at least the minimum allowable safety factor.

Dike Section "B" was found to meet the minimum design requirements. The lowest value obtained using vane shear information was found to be 1.66 in the steady seepage case.

Cost Analysis

It is recommended that the end dump method be used for construction of Dike "A" and for that portion of Dike "B" along Birch Creek. The borrow areas are conveniently located to both dike locations.

From Station 5+340 to Station 10+850, a dragline operation may be feasible because of the 5-10 feet of good borrow material, which may be adjacent to the dike alignment. It should be noted that movement of the dike centerline toward the anchorage in this area will improve the possibility of using this method of construction for this dike segment.

Unit Development Cost

Using the aforementioned construction methods and borrow sources, a budget estimate was prepared for the initial dike construction to elevation +12' above MLW. Estimated total initial cost was $730,000, or a *unit development cost* of $0.109 per cubic yard of capacity obtained.

Recommendations for Future Study

(NOTE: These recommendations will only be accomplished if an agreement with the Monsanto Company is executed).

1. Subsurface explorations still required consist of additional borings along the dike alignment to reduce the distance between individual borings (Est. Cost - $15,000).

2. Further analysis should be made utilizing the laboratory test data obtained from SADL and currently available, and test data to be obtained in the future. Use of this data could reduce dike cross-section.

A survey of the river bottom from the 40' line of the anchorage to the centerline of the proposed dike should be made. Using this data a complete analysis of the slope stability should be made to determine the minimum allowable distance from top of anchorage side slope to toe of the dike. This is believed to be a most important phase of the final design, since after analysis of topographic (and soil) data, as much as 40 additional acres of disposal area may be added by moving the dike centerline to a location within 300' of the top of the anchorage side slope.

APPENDIX C

TINICUM DISPOSAL AREA

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PURPOSE

Tinicum Disposal Area has been considered a potential disposal area for many years. This area is geographically located to well accommodate dredging from Mantua Creek Anchorage as well as adjacent channel maintenance dredging.

LOCATION:

The proposed Tinicum Disposal Area is located along the Delaware River - Pennsylvania shoreline in the upper portion of the Little Tinicum Island back channel. The disposal area encompasses a portion of Little Tinicum Island and the riparian lands of the back channel. Little Tinicum Island is located in the Delaware River approximately 5 miles downstream of the confluence of the Schuylkill River.

OWNERSHIP:

The riparian lands of the Delaware River back channel of Little Tinicum Island are owned by the Commonwealth of Pennsylvania. Little Tinicum Island is owned by the Tinicum Real Estate Holding Corporation.

HISTORY:

The Philadelphia District originally proposed fee acquisition of this area in 1964, to provide an area for the proposed dredging required to enlarge Mantua Creek Anchorage to authorized dimensions. The acquisition of Tinicum Disposal Area was officially deferred in May 1965 pending acquisition of a more feasible disposal area for Mantua Creek Anchorage; the National Steel property.

ACCEPTANCE:

During the original proposal to develop a Tinicum Disposal Area, objections were voiced by various interests. A major opponent to this project was the Westinghouse Corporation, whose Lester, Pa., plant is located behind a portion of the proposed disposal area. Westinghouse objected, declaring that this disposal area development would preclude their access to navigable water required for future waterborne shipments of Lester Plant products. Westinghouse was quite vehement in their opposition. Westinghouse distorted our plan of development to other interests to gain support for their opposition. It was suspected that the reason for Westinghouse's opposition was that the disposal area development was being groomed as an excuse by Westinghouse to close and relocate their Lester Plant. The Lester Plant has been plagued with labor and worker strikes.

In early 1967 it was determined that Tinicum Disposal Area was an important area required for the short range solution for disposal of material dredged from the Delaware River. It was concluded that the key to making this area a reality was to gain public acceptance of the project. The efforts of the District were immediately directed toward gaining this acceptance.

The major complaint from the local landowners and industries along Little Tinicum Island back channel was that the proposed disposal area would further compound a problem they had been combating for many years; shoaling in the back channel. Under the direction of the District Office, tests were conducted in the Delaware River model at the Waterways Experiment Station at Vicksburg. The model tests revealed that the back channel, closed off without an access channel, showed a decrease in shoaling and the opposite effect with an access channel. The model results were discussed with the local in-

terests. Their objection to the project remained firm.

A study of the shoaling conditions in Little Tinicum Island Back Channel and the dredging which would be required to provide a navigable channel, revealed that this work could be accomplished and justified by the Corps of Engineers as a Section 107, Small Navigation Project. It was found that this navigation project also supports the disposal area development by providing some material for the initial construction of disposal area dikes. In addition, the navigation project provides the means for obtaining public acceptance to the Tinicum Disposal Area. The disposal area also provides for economical future maintenance dredging of the navigation project.

The proposed development of Tinicum Disposal Area and the navigation project in Little Tinicum Island back channel was presented to local interests by the District Engineer in a meeting held by Congressman Lawrence G. Williams, Pa., in July 1967. Our proposals were accepted.

A reconnaissance investigation, subject: "Delaware River Back Channel at Tinicum Township, Pa." was completed by the Philadelphia District on 1 March 1968, approved by NAD 26 April 1968 and forwarded to OCE with the recommendation that funds in the amount of $31,300 be made available for the detailed study of this navigation project. This study was initiated in July 1968 and was scheduled for completion in January 1969, but due to a request by Westinghouse, additional model tests are underway.

ENGINEERING CONSIDERATIONS:

Subsurface Explorations and Testing

Subsurface explorations for the preliminary design of the disposal area were performed during September 1968. The main exploratory effort was concentrated along the proposed dike alignment to determine the existing foundation conditions along this alignment. In addition to this effort, other borings were made to determine: (1) possible borrow sources; and (2) the type of material to be removed from the channel excavation to be made across Little Tinicum Island immediately downstream of the proposed disposal area. Locations of all borings and detailed information concerning these borings are shown on plates 7 and 8.

Borings were made by the wash boring and "dry" sampling method using four-inch diameter casing. Sampling included both disturbed and undisturbed sampling. Drive (disturbed) samples were taken with both two and three-inch diameter split spoon samplers. A limited number of undisturbed samples were taken in selected locations using a 3-inch stationary piston sampler. Vane shear tests were also made (using a 3-inch diameter vane) to determine the insitu strengths of cohesive materials encountered in the foundation along the proposed dike alignment. Drill rigs used in the drilling program consisted of a motor driven cathead with independent tripod arrangement. For drilling in the comparatively deep water areas, a drill rig mounted on a large wooden barge (barge dimensions, approximately 20' x 60') was employed to provide a stable drilling platform in the rough waters occasionally encountered in these areas. For borings in the tidal flat areas, the contractor employed a smaller rig mounted on a shallow draft barrel float (approximate dimensions 10' x 15'). This float also provided transport for the rig and other equipment to Little Tinicum Island, where they were offloaded and used to drill the holes located on the island.

Soils testing accomplished to date has been limited to a laboratory review of visual classifications and moisture content determinations (the latter on cohesive soils) on the disturbed samples obtained during these explorations. Undisturbed samples will be tested to determine shear strength and consolidation characteristics to verify preliminary design values which are based upon vane shear test data and standard penetration tests.

Subsurface Conditions

Foundation conditions along the proposed dike alignment range from good to poor. The poorest conditions encountered were found in the segments located between the mainland and Little Tinicum Island at the downstream end of the area (Sta. 0+000 to Sta. 2+200) and the segment extending between the upstream end of Little Tinicum Island to the land connection in the vicinity of Bar '57 (Sta. 8+400 to Sta. 11+100). The foundation in these areas consists of very soft to soft organic silts and clays ranging from 10 to 25 feet in thickness. This is underlain by loose to medium dense stratified sand and silt. The remaining portions of the alignment, which are on or adjacent to Little Tinicum Island and on the mainland side of the area, are located over fair to good foundation materials consisting of silty sands and sands with silt and clay layers. These materials are in loose to medium condition as determined from standard penetration tests.

Explorations for borrow sources made within the disposal area limits disclosed several possible borrow sources. The most promising of the sources is located on the island side of Little Tinicum Island. This source consists of: (1) an existing filled disposal area on the island containing some 200,000 cubic yards of suitable silty fine to coarse sand borrow from El. +5 to average top elevation of +19; and (2) silty fine to coarse sand below this material from El. +5 to El. -15, within the existing disposal area and from the island adjacent to the area. In addition to this, approximately 75,000 cubic yards of gravelly sand would be excavated during the channel excavation through the island. All the above borrow could be excavated by dragline and hauled by truck to the dike. Enough material is available on and adjacent to the island to complete all Stage I diking (to El. +15). The borrow source from El. +5 to El. -15 may require wasting of a strata of from 2 to 5 feet of silt and clay material, which occurs between El. 0 and El. -5. This would require selective excavating and placing procedures during the excavation operations at this level.

Dike Design

It was assumed that initial dike development would be to El. +15 with subsequent raising occurring incrementally as needed with material for raising coming from dried out dredge spoil from inside the area. The development procedure permits the poor foundation material to consolidate and gain strength so the final section can be considerably smaller than if rapid development to full height was used.

The proposed dike alignment for Stage I development of the disposal area is shown on plate 7. It utilizes existing diking on Little Tinicum Island and the inland borders of the area. Except for minor reshaping, the existing dikes will be adequate for first stage development to El. +15. New dike construction will be required from Sta. 0+000 to Sta. 3+230 and from Sta. 4+690 to Sta. 11+880. The basic first stage design is shown on plate 8. The

section has 1 on 5 side slopes from existing ground to El. +8, and 1 on 3 slopes from El. +8 to the top of dike El. +15. The top width is 20 feet and displacement and consolidation allowances of from 1 to 4 feet beneath the dike section have been included in the design. Riprap will be placed between El. +8 to El. -1 along major portions of the dike section facing the Delaware River and Little Tinicum Island back channel. The length of diking requiring riprap protection is shown on plate 7.

The overall plan for development of the Tinicum Disposal Area calls for final top of fill elevation of +35. The proposed method of raising the dike from the first stage top of dike El. +15 to the final top of dike El. +37 is to construct a series of incremental dikes (individual 3 to 4 foot increments). As discussed previously, these incremental dikes will be constructed from fill material immediately adjacent to the dikes on the inside of the disposal area. It is anticipated that this material will require some drying time (between one and two months) between the time it is placed and the time it is compacted and filling behind the incremental dike is allowed to proceed. A filling rate of 2 feet per year should be considered the maximum allowable rate above El. +15 to avoid overstressing of the foundation. Proper selection of discharge pipe locations along the inside perimeter of the dikes causing placement of granular materials in these areas will provide a stronger dike section and may allow the placement and compaction of the incremental diking in one operation without the drying cycle requirement. The overall dike slope (toe of Stage I to top of proposed dike) should be maintained at a slope no steeper than 1 on 5 during all stages of incremental dike construction as shown on the sections on plate 8.

The dike sections for Stage I development were determined by use of the Swedish Arc Method of slope stability. The cases investigated were the as-constructed (controlling condition for the inside slope) and steady seepage cases (controlling condition for the outside slope). It was assumed steady seepage could develop through the granular dike due to filling prior to consolidation and increased strength within the foundation. Design strengths for foundation materials were thus based upon present strength as determined from vane shear tests performed during explorations. A safety factor of 1.2 was established as the minimum allowable for this design and the minimum computed factor of safety was 1.3 (steady seepage case).

Construction Methods

Information currently available indicates that the end dump method of dike construction should be employed using the Little Tinicum Island source previously described as a borrow source. This will require dragline or clamshell bucket excavation of the major portion of the borrow with approximately 60 percent of this excavation to be performed in the wet. As mentioned in Section B-2, a portion of the material within the proposed borrow limits will be wasted because of its unsuitability for use in the dikes. In addition to this, selectivity in handling of the excavated materials will be required to insure that the heavier granular materials are used in those portions of the dike constructed below normal high water. Shaping of the upper portions of the dike will be required prior to beginning filling operations.

A possible alternative method, which may be used if adequate subaqueous borrow sources are available outside the disposal area, is to construct the deep

water sections of the dike (specifically Sta. 0+000 to 2+200 and 8+500 to 11+200) by the hydraulic fill method. No readily available borrow source for this type of construction was located inside of the disposal area. Some sand and gravel zones were located inside the area but these are overlain by 10 to 25 feet of silt and clay materials, which would have to be removed before the granular materials could be reached. In reference to the construction of dikes by the hydraulic fill method, local interests will probably strongly object to the use of this method.

Unit Development Cost

Using the aforementioned construction methods and borrow sources, a budget estimate was prepared for the initial dike construction to elevation +15' above MLW. Estimated total initial cost was $1,053,000, or a unit development cost of $0.097 per cubic yard of capacity obtained.

Recommendations for Further Study

Detailed design of the area would require the following: subsurface explorations consisting of additional borings along the dike alignment to more closely define foundation conditions (estimated cost $15,000) and borings to further delineate borrow sources on Little Tinicum Island. The need and/or desirability for a subaqueous source of borrow to permit hydraulic fill placement would have to be evaluated at the time of final design. If construction is several years in the future, the borrow source as described herein might have been used elsewhere, making it essential to locate other sources. This investigation cost is estimated at $10,000.

Actual design costs for the final design of the Tinicum Disposal Area, including plans and specifications, are estimated to be in the $30,000 to $35,000 range.

APPENDIX D

CHESTER-MONDS ISLAND DISPOSAL AREA

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PURPOSE

This proposed Chester-Monds Island Disposal Area is located along the critical shoaling region of the Delaware River. This area has potential use for deposition of material dredged by hopper dredge from the 40-foot channel in Marcus Hook Range. It can also be used for the hydraulic dredging of both Marcus Hook and Mantua Creek Anchorages; however, booster pumping is necessary.

In the long range plan, the Chester-Monds area becomes important when other present existing disposal areas become consumed, necessitating that dredged material be moved greater distances to a depository site.

LOCATION

The Chester-Monds Island Disposal Area is located on the New Jersey side of the Delaware River across from Chester, Pennsylvania. The proposed development of this area includes the existing Chester Island and Monds Island and riparian land between and downstream of the Islands; see Plate 9.

OWNERSHIP

All of the water areas within the proposed disposal area are considered State of New Jersey riparian lands. All of Chester Island and a portion of Monds Island is also state land. The state acknowledges that a small portion of Monds Island is owned by E.I. du Pont de Nemours & Co.

HISTORY

The Chester-Monds Island Disposal Area has been considered for development in the past. A portion of Monds Island was filled in connection with Government dredging operations in the late 1930's.

ACCEPTANCE

To insure acceptance of this proposed disposal area, the Philadelphia District presented the plan of development to the State of New Jersey Department of Conservation and Economic Development in May 1967. The State concurred with our proposed development.

To further coordinate the future development of the Chester-Monds Island Disposal Area, a meeting was held with E.I. duPont de Nemours & Co., a landowner of a portion of the proposed area, on 15 May 1967. (The Repauno Plant of DuPont Company is located upland behind a portion of the proposed disposal area.) DuPont has been receptive in the past to having a disposal area developed in the Chester-Monds Island area, however, they have become involved in a legal disagreement with the State of New Jersey over claimed ownership of land. The State of New Jersey is claiming ownership to riparian land to which DuPont claimed to hold fee title. This question of land ownership is yet to be resolved.

ENGINEERING CONSIDERATIONS

Subsurface Explorations and Testing

The subsurface explorations for the preliminary design of the disposal area diking was performed during June and July 1967. The main exploratory effort was concentrated in the area of the State I development adjacent to Chester Island and Monds Island (as shown on Plate 9). Several borings were made to determine foundation conditions in the area downstream of Chester Island for the possible subsequent expansion of the disposal area, and in addition, a total of four borings were made on the east side of Little Tinicum Island between Delaware River Centerline

Stations 82+000 to 92+000 to determine the borrow capability of that area.

The explorations were made by the wash boring and "dry" sampling method using 4-inch diameter casing. Sampling included both drive and undistrubed sampling. Drive samples were taken with 2-inch or 3-inch borings using a 3-inch diameter stationary piston sampler. In addition to the sampling program, 3-inch diameter vane shear tests were made to determine the insitu strengths of the cohesive materials encountered along the proposed dike alignment.

Plate 10 shows the final depths of the borings, the numbers and locations of undisturbed samples taken and the vane shear test performed.

The contractor employed two types of water transport for his drill rigs. For holes drilled on the river, the rig was mounted on a large metal barge because of the rough water that is common in the area and the depth of water at some boring locations. For holes drilled on the islands, a drill rig was mounted on a barrel float and transported from the mainland to the island and from location to location on the islands. The rig was unloaded from this barge and moved onto each hole location. This method of transport was chosen by the contractor due to the heavy growth on the islands which made moving rigs overland difficult. The drill rigs used were of standard rotary design.

Selected undisturbed samples were sent to South Atlantic Division Laboratory for testing. Tests performed included 3 point "Q" tests, 3 point "R" tests, consolidation tests or a combination of these. Classification of all disturbed samples was reviewed in the District Laboratory and water contents were made on most silts and clays. Mechanical analyses were run on some samples to determine the grain size distribution of the +200 size material.

Subsurface Conditions

Foundation conditions along the proposed dike alignment range from fair to poor. The most favorable foundation condition is found in the segment between Chester and Monds Islands. In this section the foundation materials generally consist of silty sand and clean sand with intermittent zones of organic silt. The materials along this portion of the dike alignment are generally in a medium to dense condition, as determined from standard penetration test, and are considered fair to good foundation for dike construction. Along remaining portions of the alignment foundation materials are composed of soft to very soft organic silts and clays extending to a depth of at least ten feet below the ground surface. This foundation is considered to be poor for dike construction and will require a substantial dike section for stability.

During the explorations a potential subaqueous borrow source was found in the area encompassed by DKE-23, 22, 40 and 20. This borrow material is predominantly composed of sands and silty sands containing an average of approximately 25 percent fines and extending from ground surface to an average depth of approximately 40 feet below ground surface. It is estimated that pumping losses for this material, if used in the construction of a pumped dike section, will be approximately 30 percent. Final development of this borrow source will consider the consequences of these pumping losses on shoaling. Upgrading of the material in an enclosed area may be necessary.

No exploratory borings were made on the mainland to determine a source of land borrow for the diking. Borings made on Chester and Monds Islands showed no extensive borrow sources of satisfactory material available at either location. Surface features on the mainland indicate that satisfactory borrow sources are available within one mile of the site. For most part, these sources are undeveloped and are located on privately owned lands. A commerical source is available approximately one-half mile off the site.

Dike Design

The general dike alignment proposed in the preliminary design is shown on Plate 9 and follows the alignment determined from the hydraulic model of the river. This alignment was modified where it was felt advisable to take advantage of more favorable subsurface and/or surface conditions.

The outer dike extends from the upstream end of Monds Island to Chester Island and from Chester Island to the mainland. The inner dike follows the present Monds Island dike line adjacent to Aunt Debs Ditch to the downstream end of Monds Island. From this point the alignment is over tidal flats to a point immediately downstream of the Repaupo Creek Tidal Gate. The dike ties into an existing dike at this point, which continues to the intersection with the outer dike extending from Chester Island to the mainland.

The design presented herein is based upon the assumption of staged construction. The first stage will consist of a section with 5:1 side slopes, top width of 15 feet and top elevation of +12. An average allowance of 3 feet has been provided for consolitation and/or displacement of foundation material during the first stage construction. This displaced material consists of soft to very soft organic silts and clays.

The raising of the dikes above elevation +12 will be made with a series of incremental dikes to a final top elevation of +27. This method is based upon the use of materials immediately adjacent to the dikes on the inside of the disposal area as a borrow source for the incremental diking. This design assumes that the discharge of dredged materials being pumped into the disposal area will be along the inside perimeter of the dike. In addition to providing a solid base of granular material for the incremental diking, this method of discharge provides good diking material next to the dike. The typical dike section is shown on Plate 10.

Riprap will be placed on all dike sections subject to wave action if excessive erosion of the 5:1 outer slopes occur during or after construction.

The dike section design was determined by use of the Swedish Arc method of slope stability. The cases investigated were the as-constructed and steady seepage cases. Design strengths for foundation materials were based upon vane shear tests performed during the explorations. The adopted design values are shown on Plate 10. Although a safety factor of 1.20 is the minimum allowable for this design, the smallest safety factor obtained in the computations for this section was 1.45 ("Q" case steady seepage).

Construction Methods

Because of the location of the subaqueous borrow source within the limits of the disposal area, the use of the dredged in-place dike section would be the most economical method of construction, if a final analysis concludes that such an operation is permissible.

An alternate method of construction would be as follows:

A dragline constructed dike between the upstream end of the Monds Island and the downstream end of Chester Island, using material adjacent to the dike alignment throughout this section.

A land haul operation (maximum haul distance one-half mile) using a dumped fill dike to construct the inner dike and that portion of the outer dike between the downstream end of Chester Island and the mainland.

A land borrow investigation should be made to determine whether or not an adequate land source of borrow is available with a reasonable haul distance in the event hydraulic construction cannot be tolerated.

Unit Development Cost

Using the aforementioned construction methods and borrow sources, a budget estimate was prepared for the initial dike construction to elevation +12' above MLW. Estimated total initial cost was $1,543,000, or a unit development cost of $0.096 per cubic yard of capacity obtained.

Recommendations for Further Study

Subsurface explorations still required for final design consist of additional borings along the dike alignment to more closely define foundation conditions (est. cost $23,000) and, if required, (see preceding para.), an investigation of a land borrow source (est. cost $7,000).

The following alternate schemes for development of the disposal area should be studied during the final design phase:

Diversion of Repaupo Creek and other streams emptying into the River through tidal gates to reduce the length of the portion of Aunt Debs Ditch, which will remain open. Reduction of this length would result in a realignment of the inner dike and a substantial savings in diking cost. A further cost reduction could possibly be obtained by use of materials removed due to this diversion of stream paths in the dike.

Extension of Stage I construction to include the area downstream of Chester Island using an alignment through borings DKB-15, 11, 9 and 10.

Further study of sections to be used, employing all data available after accomplishing the aforementioned investigations.

APPENDIX E

CONSOLIDATION STUDY OF DREDGE SPOIL

TABLE OF CONTENTS

I. PURPOSE AND SCOPE.

The purpose of this study is to investigate engineering characteristics of hydraulic dredge spoil deposits in regard to consolidation of the spoil and land utilization. The dredge spoil of interest is from maintenance operations in the Delaware River between the cities of Philadelphia, Pennsylvania and Wilmington, Delaware. Four disposal areas, considered typical and representative of the spoil deposits in this section of the river, were selected for investigation. These areas are located as shown on Plate 11 and listed in order proceeding downstream are Darby Creek, Oldmans No. 11, Edgemoor, and Pigeon Point.

The scope of work included field exploration of subsurface conditions, laboratory testing of the materials, and preliminary engineering studies of stability and settlement characteristics, types of foundations adaptable to the deposits, and methods of improving the spoil. The studies are concerned almost entirely with fine grained spoil materials, since these comprise the bulk of the spoil produced from maintenance dredging and generate problems because of their poor quality as fill. Poor quality foundation materials present beneath the spoil in varying amounts and depths were considered outside the scope of this study.

II. DESCRIPTION AND FILLING HISTORY.

A. *Edgemoor Disposal Area.* The area, shown on Plate 12, is located on the north side of the Christina River at its confluence with the Delaware River near Wilmington, Delaware. Development as a disposal area dates back to 1910 when the extension of the bulkhead was authorized. The area occupies land which was formerly a tidal marsh with the riverward limit located in the Delaware River where water depths are about 15 feet. The original area is now subdivided into an active section and a second smaller section which is no longer used for spoil. The sections are designated on Plate 12 as Part A and Part B, respectively. Profiles, Plate 13, show the general fill elevations at the time the borings were made and other known fill elevations between the years 1911 and 1967. A dike presently subdivides Part A into two unequal portions. At the time of the explorations general surface elevations were 30 feet and 26 feet, respectively, in the larger and small portions. After completion of the explorations, dikes were raised and dredge spoil deposited, which raised the fill levels to elevations 34 and 28. Part B was last filled in 1958 and presently has a general surface elevation of 18.5 feet.

B. *Oldmans No. 1 Disposal Area.* This area, located on the south side of Oldmans Creek between Bridgeport and Penns Grove, New Jersey, has been inactive since December 1962. The land was formerly a tidal marsh. A heavily wooded section of small to medium size trees exists along the southern portion of the area that runs parallel to Route 130. The rest of the general area exhibits the thick growth of reeds which is typical of inactive areas. Present surface elevation in the area varies between 13 and 16 feet. A plan of the area and soil profiles showing known levels of the deposit are presented on Plate 14.

C. *Darby Creek Disposal Area.* This area, formerly low-lying marshy land, is located in the State of Pennsylvania. Boundary lines are approximately defined by the meandering Darby Creek in the north, State Highway 291 (Industrial Highway) in the south, the Philadelphia County

Line in the east, and Long Hook Creek in the west. Spoil was first placed in the area in 1956, and disposal use continued to 1966. Small to medium size trees and reeds cover most of the eastern part, which represents about one-third of the total area. The remainder is covered with the thick growth of high reeds. A plan of the area and the profiles with known levels for top of spoil between the original ground in 1955 to existing ground in 1967 are shown on Plate 15.

D. *Pigeon Point Disposal Area A.* The general area is located on the shore of the Delaware River south of the city of Wilmington, Delaware. It is crossed from east to west by the Reading Railroad, thus, dividing the general area into Areas A and B. This report considers Area A, which is the part north of the Reading tracks, or approximately one-third of the general area. Information on the history of this area goes back to June 1948, when the drawing for the proposed disposal area was prepared. This drawing shows that most of the area was covered with cultivated fields and that ground surface elevations were between 8 and 10 feet. Area A was last used in 1966 and is still active. The present surface of the spoil is completely covered with a thick reed growth and ranges from 24 to 26 feet in elevation. A plan of the area with soil profiles and known former spoil levels are shown on Plate 16.

III. SURFACE CONDITIONS AND TRAFFICABILITY.

The material forming the ground surface over the major portions of the four areas is the fine grained organic silt and clay typical of the maintenance dredging spoil deposits in the Philadelphia-Wilmington region. This material exhibited varying degrees of surface stability and trafficability in the four areas. In Part B of Edgemoor, inactive since 1958, the surface, except in wet weather, was dry, firm and permitted operation of a 1-1/2-ton truck during the subsurface exploration operations. In Part A, which was used in 1967, the truck bogged down on several occasions and the drilling contractor had to resort to crawler-type equipment only. Subsequent to the drilling, during the dike raising operations for spoil disposal in 1967, the surface in the upstream section of Part A, where ground water was near the surface, would not support the crane being used (operating on timber mats) until a ditch had been dug which drained substantial quantities of water from the material in the vicinity.

The surface in Oldmans area, like Part B, Edgemoor, also permitted operation of the 1-1/2-ton truck when dry, but when wet it became soft and easily rutted. A local portion near the sluice appears to remain continuously wet and soft.

The surface condition in the Darby Creek area and Pigeon Point Area A is similar to Oldmans and Edgemoor, Part B. In these areas a crawler tractor was used to pull the skid-mounted drilling equipment to the boring locations.

IV. SUBSURFACE EXPLORATIONS.

Borings were made in the four areas as shown on Plates 12, 14, 15 and 16. The borings were drilled by Warren George, Inc. under the supervision of a soils engineer from the Philadelphia District, Foundations and Materials Branch. Locations of the bore holes were established in order to evaluate subsurface conditions in the general direction of flow from pipeline discharge points to the sluice, and to provide area coverage for determination of average properties of the spoil. All

bore holes were drilled to a diameter of 6 inches to accommodate a 4-1/2-inch diameter undisturbed stationary piston tube sampler. Sampling by means of a 2 or 3-inch diameter driven split spoon (penetration test) or the piston sampler was continuous, except where vane shear tests were performed in the bore holes. The number of borings and depth range in the four areas were as follows:

Area	No. of Borings	Depth Range (ft)
Edgemoor	10	25 to 36
Oldmans No. 1	6	16 to 24
Darby Creek	5	16 to 25
Pigeon Point	6	35 to 42

V. LABORATORY TESTS.

Detailed laboratory tests were conducted at the New England Division Laboratory on the undisturbed stationary piston tube samples from the four areas. These tests included unit weight, grain size, Atterberg limits, specific gravity, "Q" and "R" triaxial compression, and consolidation tests. Routine tests to obtain the moisture content, Atterberg limits, and grain size were made on the major portion of the disturbed samples by the Philadelphia District Laboratory. Details of the laboratory testing and test reports are presented in Appendix B.

VI. RESULTS OF INVESTIGATION.

A. *Subsurface Conditions.* The materials in the four areas are quite similar, being classified primarily as soft to very soft organic silts and clays. Gradation curve bands for the organic silts and clays are shown on Plate 17. They are usually highly plastic and predominantly dark gray in color, but range to grayish brown from effects of oxidation. The organic content consists of very finely divided particles (colloids) present in the original material and the remains of successive reed growths filled over during the spoil placement. By visual inspection and penetration testing the fine grained materials are soft, have high water contents, low shear strength and high compressibility, and are a poor quality material throughout the depths of the deposits. Granular material, sands and silty sands as separate zones and layers, form a small percentage of the total material, except in Darby Creek area where a sizeable portion contains granular material. Groundwater, for the most part, is only a few feet below the surface, including the inactive part of Edgemoor area which was last used nine years before the explorations. Depths to groundwater, as observed during the investigations, and the time of the last prior deposition of spoil are shown in Table 6-1. The indication of greater depth to the water level in Pigeon Point area is affected by the proximity of most of the borehole locations to the exterior dikes.

B. *Test Results.*

1. *Moisture Content.* The water content of the fine organic silts and clays in the four areas is high, typically 70 to 100 percent of the dry weight of soil. Dry densities are correspondingly low, usually 48 to 58 pcf (pounds per cubic foot). Average results of the moisture content and density tests for each boring and for each area are summarized in Table 6-2. For the four areas, the average moisture content is 83 percent, and the average dry density is 53 pcf. Water contents for individual samples are shown at their corresponding depth in the profiles on Plates 13

TABLE 6-1

Disposal Area	Date of Last Fill	Groundwater Depth (ft)	
		Area Range	Area Avg.
1. Edgemoor			
Active, Part A	May 1965	0.5 - 1.8	1.2
Inactive, Part B	1958	3.5	3.5
2. Oldmans No. 1	Dec 1962	1.5 - 4.0	2.6
3. Darby Creek	Nov 1966	2.0 - 5.4	3.1
4. Pigeon Point Area A	May 1966	4.5 - 8.1	6.8

through 16 and are plotted graphically on the "Logs of Soil Properties" in Appendix B. The general trend is lower water contents with increased depth.

2. Plasticity. Results of the Atterberg limits testing conducted on samples of the fine materials from the four deposits are plotted on the plasticity chart, Plate 18. This chart demonstrates the similarity of the materials in the four areas and the abnormally high liquid limits stemming from their organic content. The samples classify as organic clays and organic silts of high plasticity, which have very poor characteristics as foundation materials. Results of the Atterberg limits tests and the activity ratios obtained are shown graphically in Appendix B on individual "Logs of Soil Properties."

3. Shear Strength. Table 6-3 presents, for fine grained material in the four areas, the range and average values of shear strength as determined by insitu vane shear testing and "Q"-type triaxial compression tests on tube samples. The strengths are low and in the range usually found for this type of material, indicating a consistency range of the fine spoil de-

TABLE 6-3

SHEAR STRENGTH - FINE GRAINED SPOIL

Area	Shear Strength TSF*	
	Range	Average
Edgemoor		
Part A	0.05-0.28	0.19
Part B	0.30-0.41	0.33
Oldmans No. 1	0.07-0.48	0.20
Darby Creek	0.05-0.42	0.29
Pigeon Point	0.09-0.55	0.25
*Tons per square foot		

TABLE 6-2
MOISTURE CONTENT AND DENSITY - FINE GRAINED SPOIL

Area Filling Period Boring No.	Spoil Depth (ft.)	Average Per Boring		Area Average	
		MC (%)	Dry Den. (pcf)	MC (%)	Dry Den. (pcf)
Edgemoor - Part A (1911-67)					
EBB-1	30	82.4	48.4		
EBB-2	30	82.7	49.9		
EBB-3	29	97.2	44.6		
EBB-4	30	99.6	55.7	93	49
EBB-5	36	102.3	42.0		
EBB-6	26	91.6	49.0		
EBB-7	30	93.9	48.5		
EBB-8	30	92.1	52.0		
Part B (1911-58)					
EBB-9	20	78.9	53.3	70	58
EBB-10	23	61.8	63.3		
Oldmans (1946-63)					
EAB-1	10.6	82.0	51.6		
EAB-2	11	76.0	53.7		
EAB-3	11	83.4	52.2		
EAB-4	8.8	79.4	52.6	84	52
EAB-5	10.6	85.6	52.6		
EAB-6	8.5	95.8	47.0		
Darby Creek (1956-67)					
ECB-9	15	61.3	60.6		
ECB-10	13	81.3	53.9		
ECB-11	7.5	86.3	49.9	84	52
ECB-12	12.5	93.1	48.0		
ECB-13	7	98.4	48.7		
Pigeon Point (1948-66)					
DFB-57	14.2	73.0	55.3		
DFB-58	19.8	74.3	50.2		
DFB-69	19.0	65.0	57.8	76	54
DFB-60	14.9	87.9	46.4		
DFB-61	14.1	77.6	60.3		
DFB-62	18.7	80.3	50.9		
AVERAGE FOR ALL AREAS				82	53

TABLE 6-4

CONSOLIDATION DATA - FINE GRAINED SPOIL

Area	No. of Tests	Depth Range (ft.)	Range and Average Values			
			Compression Index Cc		Coefficient of Consolidation, Cv (in^2/min)	
Edgemoor						
Part A	10	2-36	0.51-1.45	0.98	0.00067-0.00150	0.00102
Part B	2	12-20	0.48-0.50	0.49	0.00463-0.00463	0.00463
Oldmans No. 1	2	6-10	0.90-1.28	1.09	0.00065-0.00100	0.00083
Darby Creek	1	7-8	0.39	0.39	0.00120	0.00120
Pigeon Point	3	6-20	0.75-0.96	0.83	0.00060-0.00100	0.00084

posits varying from very soft to soft. The tests show that while shear strength of the material would be a governing factor in construction of fills and design of structural foundations, the strengths are not so low as to indicate any possibility of sinking of construction equipment by breaking through a top crust. It is further concluded that the dredge spoil in these areas is at least the equal and on the whole is better than the materials in the former marshes, the properties of which are known in a general manner from investigations in other similar marshes.

4. *Consolidation Tests.* Results of consolidation tests on samples from the four areas presented in Appendix B as pressure-void ratio curves and time consolidation curves show that the organic silts and clays are highly compressible. The range and average values of the compression index (Cc, dimensionless) and the *coefficient of consolidation* (Cv, in square inches per minute) computed from the test results are listed in Table 6-4.

Comparisons of overburden pressures with the preconsolidation pressures indicated by the pressure-void ratio curves were made using data from the better quality undisturbed samples (those with sharp changes in the slope of the recompression and virgin portions of the pressure-void ratio curves). These comparisons, shown in Table 6-5, indicate that samples of the fine grained spoil in the four areas are either fully consolidated under the present overburden loads, or slightly preconsolidated. The preconsolidation shown by about half the samples is apparently the result of drying during the different levels of disposal area filling.

The fully consolidated and preconsolidated condition of the samples indicate that no further increase in density will occur unless there is a change in other factors which affect the soil loading. For material below the surface crust, the position of the water table is the only other factor subject to significant change. Since Table 6-1 indicates that changes in the water table occur very slowly after an initial quick drop to a few feet below the surface, it appears that without provisions to aid in drainage, there will be no further consolidation of the fine grained deposits.

TABLE 6-5

CONSOLIDATION AND OVERBURDEN PRESSURES - FINE GRAINED SPOIL

Sample	Depth (ft.)	Pre-Consolidation Pressure (T/sq. ft.)	Overburden Pressure (T/sq. ft.)
Edgemoor (Part A)			
EBB-1 (UD-2)	13-15	0.33	0.22
EBB-2 (UD-3)	22-24	0.57	0.36
EBB-3 (UD-2)	12-14	0.30	0.20
EBB-5 (UD-6)	34-36	0.48	0.49
EBB-6 (UD-4)	29-31	0.50	0.43
EBB-8 (UD-2)	10-12	0.33	0.18
Edgemoor (Part B)			
EBB-9 (UD-2)	12-14	0.45	0.33
EBB-9 (UD-3)	18-20	0.47	0.41
Oldmans No. 1			
EAB-1 (UD-1)	6-8	0.38	0.20
EAB-2 (UD-1)	12-14	0.42	0.37
EAB-6 (UD-2)	12-14	0.25	0.23
Pigeon Point			
DFB-58 (UD-1)	12-14	0.45	0.42
DFB-60 (UD-1)	6-8	0.70	0.33

VII. ANALYSIS AND DISCUSSION.

A. Drying Time for Equipment Operation and Agricultural Use. Surface conditions permitting operation of equipment and sufficient strength in the material beneath to preclude break through are considered to be the minimum requirements for the beginning of agricultural use and development for other uses. These conditions would insure enough depth (1.5 feet minimum) to the water table to support agricultural crops.

The required surface and strength conditions stated above are present in the inactive areas (Part B, Edgemoor and Oldmans No. 1, except near sluice) and also in the still active Pigeon Point area and the southern half of the still active Edgemoor area. These areas had drying periods after their last use of two to nine years. Part B, Edgemoor, obviously passed through the stage of minimum requirements noted above some years prior to these studies and the drying periods to achieve the minimum stage in these areas is therefore taken as two to five years, the latter period being that for Oldmans. The still wet portion of Oldmans shows that proper drainage is needed to effect drying for local areas of lower elevation where the water table stabilizes near the surface. Based on these experiences and the consolidation and strength testing together with observation of conditions in other disposal areas,

it appears that drying periods to permit use as defined above will in general vary from 2 to 5 years, but exceptionally to 10 years according to some indications. Semi-static or seasonal wet conditions require drainage for use of the land.

B. Problems in Industrial Use. Possible utilization of the areas will involve the solution of problems primarily connected with the high compressibility and low strength of the deposits. These problems are of the following nature:

1. Excessive long-term settlements and limited stability of the deposits.

2. Support of building foundations on fills, or on piles to a relatively deep stratum.

3. Settlement of yard levels, pavements and utilities with respect to pile supported structures.

4. Excavation below a high ground water level.

The following analysis considers possible solutions of these problems for utilization of the disposal areas. The computations are based on laboratory test data for samples from Edgemoor area, Part A, which is typical but somewhat more critical. Differences in the data from the four areas are minor.

C. Settlement, Bearing Capacity and Stability.

1. Stability of Fills. The stability of fills placed on the disposal areas was analyzed with respect to shear failure of the soft organic clays and silts under fill loads. Assuming conventional placement procedures, fills up to a height of 8 feet will have a sufficient factor of safety against shear failure of the underlying subsoils. Higher fills will require a controlled rate of filling so as to allow consolidation of the subsoils and a corresponding increase in shear strength.

2. Bearing Capacity. Based on an average cohesive strength of 0.2 tsf for the vane shear and "Q"-type triaxial compression tests, the allowable bearing pressure for structural footings is 0.4 tsf considering a safety factor of 2.5 against shear failure in the underlying soil. This value is low but typical for soft material such as exists in the spoil deposits. Higher pressures can be used with acceptance of larger settlements and provisions for controlled rates of load application.

3. Settlement. The settlement of structural foundations utilizing footings at a bearing pressure of 0.4 tsf was computed from the laboratory pressure-void ratio curves to be on the order of 4 inches for a 4'x4' footing and 6 inches for an 8'x8' footing. These values were determined for a spoil thickness of 25 feet. Settlement computations for varying surcharge pressures up to 0.6 tsf (about 12 feet of fill) have also been made and the results are presented on Figure 5, page 9-e, as curves of settlement versus surcharge pressure for spoil thicknesses of 15, 25 and 35 feet. The extreme magnitude of settlement in the deposits is demonstrated by these curves from which it would be concluded that final settlement of 25 to 50 percent of the total thickness of a placed fill will occur. Settlements indicated for an 8-foot fill are 2, 3 and 4 feet for respective spoil thicknesses of 15, 25 and 35 feet.

The rate of settlement for spoil deposits 15, 25 and 35 feet thick were computed for surcharges of 0.20, 0.40 and 0.60 tsf and are shown on Figure 6, page 10-e as curves of time versus percentage of ultimate settlement. Since these estimates were made for the existing condition of drainage at the top only, they are conservative and the actual rates will be much more rapid.

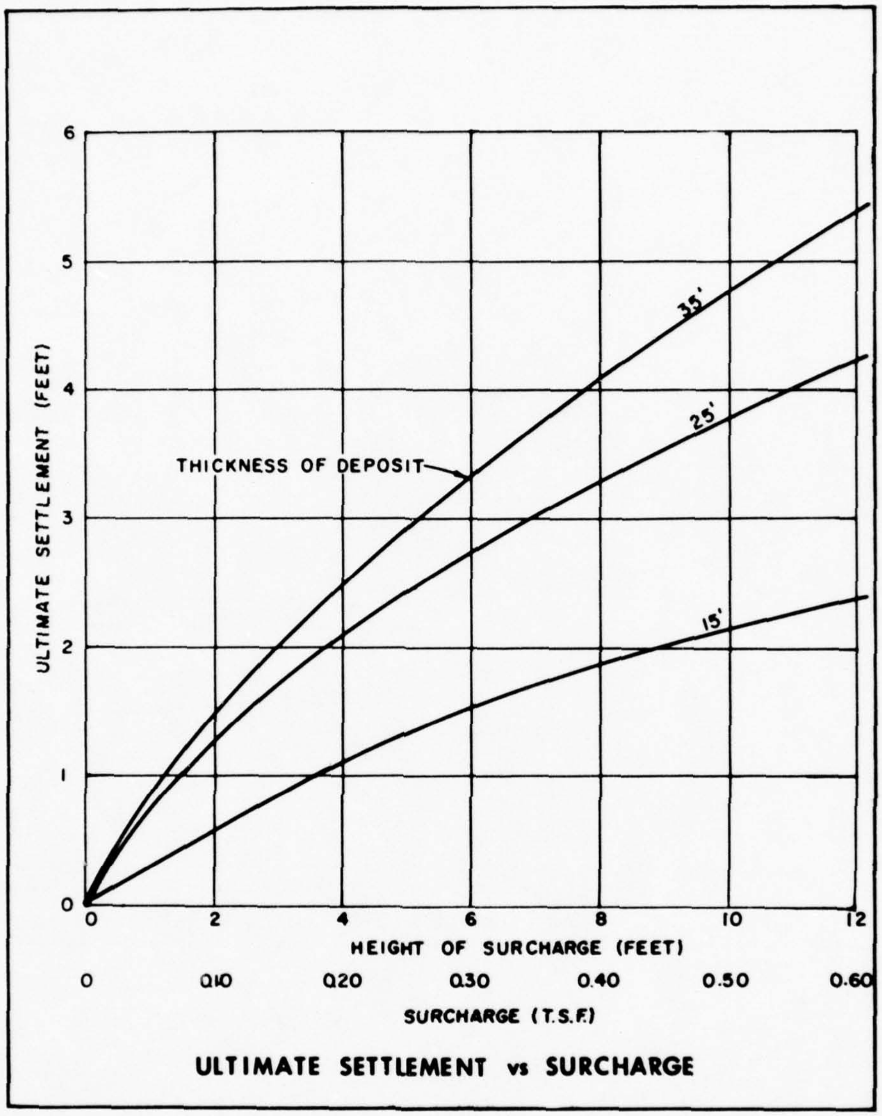
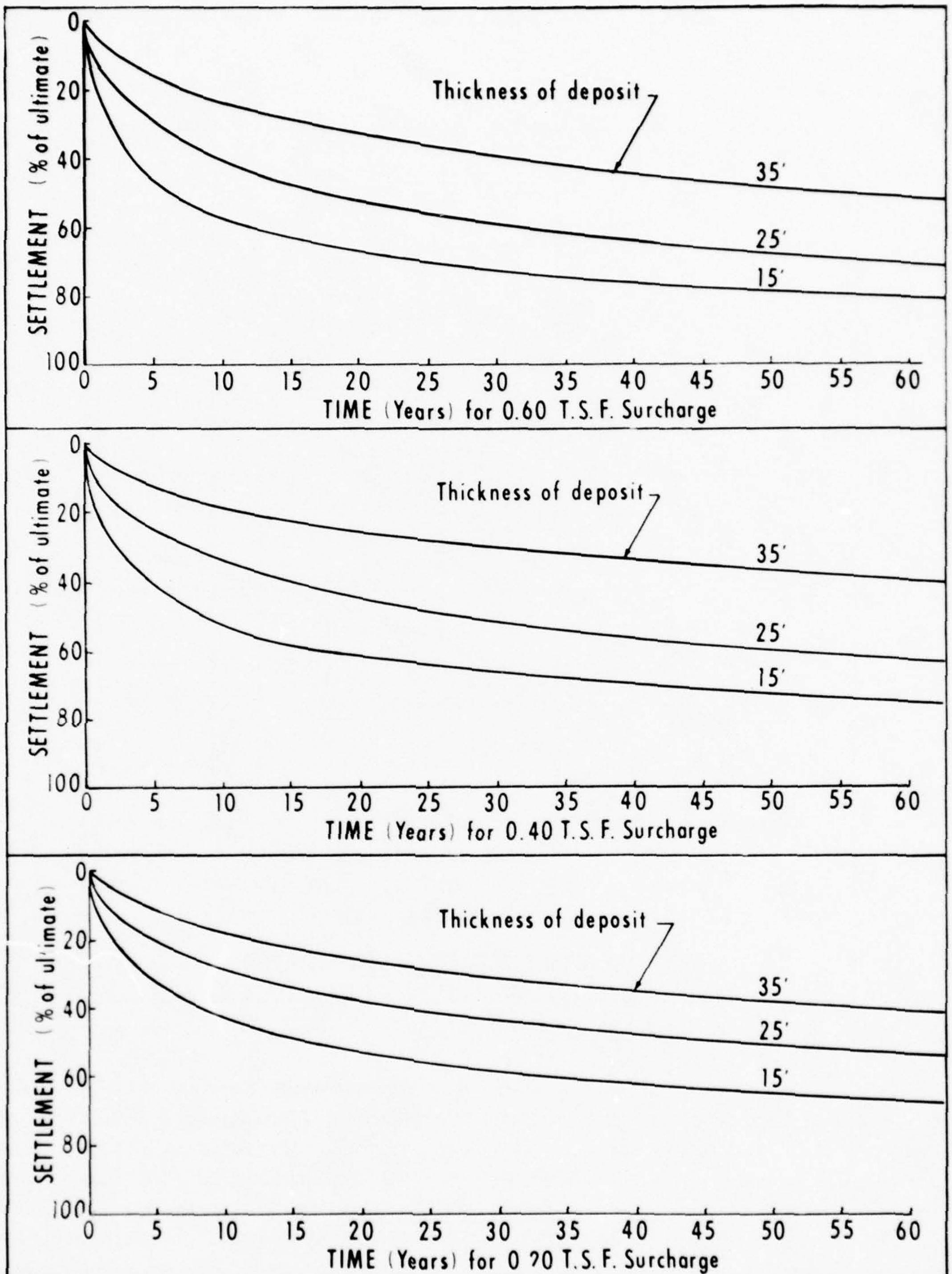


Figure 5

D. Utilization with Ordinary Site Development. It is concluded from the preceding studies that under existing conditions, the inactive areas can be developed for light industrial occupancy. Buildings to be supported on footings would be severely limited as to type and would typically consist of flexible one-story curtain wall construction which could accept significant differential settlements without damage. Footings would be limited to bearing pressures of 800-1000 psf and still ultimate settlements of 4 to 6 inches would have to be considered. Alternatively, structures could be placed on a mat or raft with basement excavation to reduce settlement or pile supported if settlements cannot be tolerated. Roadways, parking areas and building sites would require a 2-foot thick layer of compacted stable fill from an off-



RATE OF SETTLEMENT CURVES

Figure 6

site source or from local granular deposits on-site. Areas normally paved would be surfaced with a thin bituminous treatment, since periodic adjustment of surface grades would be necessary. All fill areas, the fills placed in grading and final grades, would be compacted. Utility conduits and pipes would require design to permit settlement without rupture.

As indicated by the drying periods and studies for these four areas, it would appear that development of this type for Delaware River disposal areas can generally be started two to five years after completion of filling.

VIII. METHODS OF IMPROVEMENT.

A. General. Preloading methods could be used to further consolidate the spoil and thereby reduce post construction settlement. The presettlement produced would permit greater latitude in types of building construction, reduce recurring difficulties with yard settlement around pile supported structures and reduce the settlement problems involved with pavements and utilities. Methods which could be applied and are reviewed in the following paragraphs are: (1) preloading and (2) preloading with sand drains or other types of drains to accelerate settlement. Improvement by ditching is also studied.

B. Preloading. Commonly, a preload consists of a fill equivalent to 50 to 100 percent overload maintained until the subsoils have sufficiently consolidated under the weight of the fill so as to minimize any additional settlements under design loads. The effect of different preloading pressures in accelerating subsidence of a 25-foot thick spoil deposit is shown below. The settlement times shown were conservatively determined for "single face drainage" in accordance with the conditions at the four areas. It is well established that such times are conservative with actual settlement occurring much more rapidly, since actual drainage paths for pore water transmission are much more favorable than the single face drainage assumption.

Preload Height	Preload in Tsf	Time for 12-inch Settlement in Years
4	0.20	41.0
8	0.40	7.2
12	0.60	3.1

Preloading will not completely prevent post construction settlements because of the secondary compression characteristics of some layers in the deposits. However, estimates indicate that for a typical light industrial construction, the residual post construction settlements would be within the allowable. It is concluded that preloading is an effective method of consolidating the deposits and would be applicable in development for comparatively light structures with low bearing pressures. Local spoil above the water table could be used and would be placed on a sand blanket to form the preload. The intensity of the preload pressure will be determined by the percentage of consolidation required and time available. The rate of preload placement would be limited by the strength of the spoils. Usually, the actual consolidation period is determined by field observations of settlement monuments and measurement of pore-water pressure within the compressible materials in the deposits.

C. Sand Drains. Sand drains are often used when it is desired to accelerate consolidation under a preload. The drains are formed by driving a mandrell, closed with a flap at the lower end, down through the soft material, filling with sand, then

withdrawing the mandrel. An analysis of sand drain system was made considering 16-inch diameter drains penetrating the spoil and spaced ten feet on centers. The system would require an overlaying sand blanket, approximately 3 feet in thickness, that would be drained by perforated pipes connected to a collector pipe laid along the perimeter of the area. The results of the analysis presented in Table 9-1 shows that sand drains plus a surcharge will greatly accelerate consolidation of the deposits reducing the time required for a 2 to 3 feet of presettlement in thicker deposits to 1 year or less.

Typical quantities and price ranges for treatment by the sand drain method are listed in Table 9-2, subdivided in three main categories. Land uses which would justify the treatment costs shown are limited. Examples where installations have been used are bridge approaches, airfield runways, limited access highways in urban areas, and heavy industry.

D. Improvement by Ditching.

1. General. It has been observed in at least one instance in the District that ditching has had good results in removing quite large quantities of water from a spoil area. Ditching will lower the groundwater table in a spoil area through gravity drainage of the spoil above the ditch inverts and removal of a greater portion of the rainfall as runoff compared to the present condition in which practically all rainfall is retained and replenishes the groundwater. Gravity drainage and evaporation (dessication) reduces the moisture content and produces a density increase from shrinkage under capillary tension in the material above the lowered water table. In addition, removal of the buoyancy effect within the depth of the lowered water table increases the effective weight within this depth. As a result, the underlying soil receives an additional load and undergoes additional consolidation.

2. Estimate of Results. Surface settlement due to increased density above the lowered water table can be estimated using field test data representing "before" and "after" dry densities. From Table 6-2, average "before" dry density is 53 pcf. The "after" dry density (above the water table) from limited field data is assumed to be 65 pcf, and for 15 feet of change in water table elevation, the indicated surface settlement from the density change within the 15 feet would be 2.5 feet $(15-\frac{15 \times 53}{65}=2.5)$.

The increase in effective weight from reduced buoyancy would be equivalent to addition of a 6 to 7-foot surcharge which, from Figure 5, would produce about 1.5 feet of settlement in 15 feet of underlying spoil. Thus, the combined effect for a 30-foot thick deposit with 15 feet of water table lowering would be 4 feet of change in surface elevation. Besides the density increase, other improvements would take place in aspects related to the position of the water table, such as excavation, trafficability and compactibility, and the material above the water table would provide a convenient source of borrow for use in surcharging selected areas prior to construction and for other purposes requiring common fill.

3. Ditching Plan and Cost. From observation of drying effects near sluices and adjacent to dikes in existing spoil areas, it is estimated that a system of parallel ditches at a spacing of 200 to 300 feet would be needed. This spacing assumes development of vertical alligator-type cracking of the deposits, which is usual in fine grained Delaware River spoil and which greatly increases the lateral ex-

tent of the spoil affected by drainage. The ditches would be excavated across the full width of the spoil area. Because of shear strength limitations, the ditch excavation would be performed in stages estimated at 5 feet per stage.

TABLE 9-1

SUMMARY OF SAND DRAINS STUDY

Deposit Thickness (ft)	Surcharge Pressure (tsf)	Surcharge Pressure (ft)	Surcharge Only Consolidation Time (%)	Surcharge Only Consolidation Time (Yrs)	Surcharge Plus Sand Drains Consolidation Time (%)	Surcharge Plus Sand Drains Consolidation Time (ft)	Surcharge Plus Sand Drains Consolidation Time (Yrs)
15	0.40	8	50	8	59	1.1	1/2
					83	1.6	1
					96	1.8	2
15	0.60	12	50	6	55	1.3	1/3
					75	1.8	3/4
					92	2.2	1
25	0.40	8	50	27	47	1.6	1/2
					75	2.5	1
					93	3.1	2
25	0.60	12	50	18	51	2.1	1/3
					77	3.2	3/4
					86	3.6	1
35	0.40	8	50	95	30	1.2	1/2
					52	2.1	1
					77	3.1	2
35	0.60	12	50	55	34	1.8	1/3
					61	3.3	3/4
					73	3.9	1

TABLE 9-2

TYPICAL QUANTITIES & COSTS PER ACRE
SAND DRAIN TREATMENT FOR 30 FEET OF SOFT MATERIAL

Sand Drains	13,000 L.F.	\$0.60 - 0.80	\$7,800 - 10,400
Sand Blanket	5,000 C. Y.	\$0.70 - 2.00	\$3,500 - 10,000
Surcharge	15,000 C.Y.	\$0.50 - 1.00	\$7,500 - 15,000
			\$18,800 - 35,400

TABLE 9-3

DITCHING COSTS AND SURFACE ELEVATION CHANGE

15 feet of spoil			
Ditch Depths	5'	10'	15'
Cost per Acre	$200.00	$800.00	$1,700.00
Cost per C.Y. of Spoil	$ 0.007	$ 0.03	$ 0.06
Change in Surface Elev*	1	2	2.5
Cost per C.Y. of Added Capacity	$ 0.13	$ 0.25	$ 0.41

30 feet of spoil				
Ditch Depths	5'	10'	15'	20'
Cost per Acre	$200.00	$800.00	$1,700.00	$3,000.00
Cost per C.Y. of Spoil	$ 0.004	$ 0.02	$ 0.04	$ 0.06
Change in Surface Elev*	2	3.5	4.0	5.2
Cost per C.Y. of Added Capacity	$ 0.06	$ 0.14	$ 0.27	$ 0.36

Cost for regrading: About equal to ditching costs.

*Computed assuming, for simplicity, that change in water table is the same as ditch depth.

Approximate costs for several ditch depths on a spacing of 200 feet (equivalent to 200 feet of ditch per acre) are listed in Table 9-3 on an acreage basis and also on the basis of total spoil and additional spoil capacity. From these figures a ditching program to a depth of 10 feet appears to be economically feasible and a trial installation seems desirable to ascertain ditch spacing required and degree of improvement secured. Considering increased spoil capacity, this aspect alone does not warrant the costs of ditching except in the case of shallow ditching over considerable depths (25' or more) of spoil.

IX. CONCLUSIONS.

From the investigation of engineering properties and study herein it is concluded that:

A. So far as trafficability and water table are concerned, the disposal areas can be utilized agriculturally after drying periods of two to six years. Development for industrial-commercial use can begin after similar time periods.

B. The areas can be developed for light industrial occupancy without extensive stabilization, but restrictions on building design to allow for settlement would severely limit the types of industry.

C. By use of proper stabilization procedures to minimize post construction settlement, the areas can be developed for light to medium industrial occupancy.

APPENDIX E-1

WATER CONTENT AND VOLUME CHANGES

TABLE OF CONTENTS

I. GENERAL.

In response to OCE letter dated 3 November 1967 concerning a "Proposal to Develop More Effective Use of Spoil Areas" by Joseph Caldwell, this appendix discusses volume changes of dredge spoils with reduction of water content as a means of gaining additional spoil storage capacity. The discussion is based on District experience and on water content-density data obtained in a number of projects for various types of spoil from both new work and maintenance operations. The projects were involved with dredge spoil in such ways as design and construction of structural foundations, embankments, borrow, side slopes of cuts in former spoil areas, and spoil area planning. Copies of the OCE correspondence and Caldwell's proposal are included at the end of this appendix.

II. TYPES OF MATERIAL.

As indicated by the four areas studied in this report, maintenance spoils have been chiefly organic clayey silts and sands. New work dredging materials have been primarily medium to stiff clays, sandy clays, clean sands with and without gravel, silty sands, and high plasticity organic clayey silts, similar to the maintenance materials.

III. WATER CONTENT-VOLUME.

Granular and primarily granular materials, sands, silty sands, etc. form medium density deposits, in which the additional volume changes (decrease), which occur thereafter are insignificant. Ordinarily, changes which take place are a lowering of the water table with reduced water content and reduced degree of saturation in the formerly submerged material. Water lost from the voids is replaced by air with practically no change in total volume.

Clays and sandy clays, for which the consistency is medium or greater, are separated into two portions in the dredge discharge. One portion is primarily clay lumps deposited in the vicinity of the discharge point, the remainder is liquid slurry from settlement of dispersed clay and silt particles. The clay lumps have the appearance of rounded gravel and cobbles and are undispersed clay at essentially unchanged water content. Interstices are filled with slurry or sand and slurry when sand is present in the discharge. The overall water content of such fill is increased over that of the original material, but from visual appearance and occasional testing, is insufficient to provide the basis for significant volume change. Tests have indicated water contents in the range of 20 to 35 percent and older deposits of this type are often found to be rather dense, sometimes hard, due to the effects of dessication.

The slurry portion formed in clay dredging typically ranges between 25 and 40 percent of the total spoil volume. Tests have shown water contents (below water table) of 120 to 180 percent in periods of about 2 years after placement. In older deposits, values of 30-90 percent below water table have been found. The average of 13 water content tests in one area of this type was 55 percent, which corresponds to relative volumes of 1.5 water to 1 soil. Thus, it appears that significant volume changes would result if water content could be substantially reduced and assuming that voids are correspondingly changed. In District experience, however, spoil volume occupied by material of this type has not been considered unduly large or a cause of concern. It is estimated that roughly one-half of the material is interbedded with sandy spoil or above the water table, and therefore in a denser state.

Organic clayey silts and silty clays from both new work and maintenance operations are usually encountered with low degrees of consistency (soft, very soft and semi-liquid) and are completely dispersed in the discharge. Tests of the liquid slurry which settles out commonly show densities in the range of 1160 to 1210 gm/liter (72 to 75 pcf) and corresponding to relative volumes, water to soil, of about 7 to 1. Tests, including those for this report, after periods of about 2 years show increased densities of 85 pcf (3 to 1, water volume to soil volume, 40 pcf dry) to 95 pcf (2 to 1, 52 pcf dry). This type of spoil takes up a large part of the total spoil volume in the District.

IV. METHODS OF REDUCING WATER CONTENT.

Methods of improving organic silt and clay spoils presented in this report are essentially methods of reducing their water contents. Volume changes produced are shown by the consolidation testing and the estimates of surface settlement, see Figure 5. Data presented on costs of the three methods studied indicate that, in two cases, costs are much larger that the value of the spoil capacity gained considering present development costs of approximately $0.10 per cubic yard. The third method, ditching, appears to be economically feasible for ditching depths of 5 to 10 feet.

V. POSSIBLE CHANGE IN SPOIL PRACTICE.

Concerning possible changes in spoil area practice to secure reduced water content and decreased spoil volume, data obtained for the organic silt-clays appears sufficient to show that, in order to obtain significant volume change, compaction of the material would be necessary. This in turn would involve low fill increments and drying of the material.

The need for compaction is indicated by the low unit weights determined in the field for spoil above the water table after natural drying of the spoil to a condition of less than full saturation (moist to dry in appearance). The unit weights (oven dry) are in the range 55 to 65 pcf, even with the relatively large changes in moisture content for the drier material, because of replacement of pore water by air. Further evidence of the need for compaction is the present water content condition of Edgemoor area in which spoil fill increments have been low and permitted significant drying with apparently little final benefit because of resaturation at high void ratios in following pumping stages.

Considering the compaction aspect further, densities achieved with normally used equipment and methods are approximately equal to the standard AASHO maximum density which would average about 80 pcf for the organic silt-clays. Costs of compacting earth to standard AASHO density commonly is in the vicinity of $0.15 to 0.20 per cubic yard. This would provide a 25 percent decrease in volume based on unit weights of 60 and 80 pcf, but is not favorable in comparison with present disposal area development costs ($0.10 per C.Y.) without considering other changes in practice which would be needed to permit compaction. For example, compaction of 4 cubic yards at a cost of $0.60 would provide 1 cubic yard of additional capacity.

Although the costs indicated here are high, combinations of circumstances could justify expenditures to achieve higher densities. Such circumstances might be naturally occurring disposal area conditions and use rates favorable to reduced drying and compaction costs; location in a region

of high land values, probable increased value of the spoil area land because of higher spoil density; and high cost of disposal alternatives, such as long haul. The presence of one or some of these factors for a disposal area would warrant consideration of establishing drying and compaction procedures.

In conclusion, this review indicates that where dredge spoils consist of organic silt-clays, significant reduction in spoil volume is possible, however, the additional disposal capacity gained will not justify the costs involved, except in limited situations. Changes in spoil practice to achieve a significant reduction in porosity (or increase in spoil density) would entail compaction as well as drying of the material.

C O P Y

DEPARTMENT OF THE ARMY
Office of the Chief of Engineers
Washington, D.C. 20315

In reply refer to

ENGCW-OM

3 November 1967

Mr. Lewis Caccese
Chief, Operations Division
U. S. Army Engineer District, Philadelphia
US Custom House, 2nd & Chestnut Street
Philadelphia, Pennsylvania 19106

Dear Lew:

In connection with a proposal by Mr. Joseph Caldwell to the Committee on Tidal Hydraulics to undertake a study to develope more effective use of spoil areas, you offered some comments which, in essence, indicated that the proposed study is similar to the program you have underway on the overall Delaware River study.

Inclosed is my letter of 13 October 1967 to the Committee on Tidal Hydraulics recommending that the existing study on the Delaware River be implemented where necessary to include the applicable features of the study proposed by Mr. Caldwell. It is requested that your Delaware River study incorporate the area of investigation proposed by Mr. Caldwell.

Sincerely yours,

/s/ E. B. Conner
E. B. CONNER

2 Incls:
1. Cpy ltr fm Mr. Caldwell dtd 15 Jan 65
2. Cpy ltr fm Mr. Conner dtd 13 Oct 67

COPY

DEPARTMENT OF THE ARMY
Office of the Chief of Engineers
Washington, D.C. 20315

In reply refer to

ENGCW-OM 13 October 1967

SUBJECT: Proposal to Develop More Effective Use of Spoil Areas

TO: Committee on Tidal Hydraulics
Vicksburg, Mississippi

1. The proposal submitted by Mr. Caldwell to develop more effective use of spoil areas through reduction of the water content is one of many worthwhile considerations being given to the problem of spoil disposal.

2. The area of investigation proposed by Mr. Caldwell is being covered by the Philadelphia District in their Long Range Spoil Study.

3. The suggested program is quite similar to the program which the Philadelphia District has had underway since the first of the year. At the present time borings have been completed at two disposal areas to determine the condition of the fill at various depths. These samples will be compared with the placement data to learn as much as possible about spoil deposits and to utilize the information to upgrade the quality of fill which includes consideration of means to rapidly dissipate excess water.

4. While the studies being made on the Delaware River by the Philadelphia District are not quite as extensive as proposed by Mr. Caldwell they could easily be expanded within the present program. The funding of the over-all Long Range Spoil Disposal study is by operation and maintenance funds presently estimated at $750,000. Whatever additional funds might be needed to carry out Mr. Caldwell's proposal on a scale adaptable to the Delaware River could be accomplished with operation and maintenance funds.

5. It is doubtful if anyone could contribute more to this proposal than the Philadelphia District in view of their current studies on spoil disposal and availability of operation and maintenance funds for that purpose.

6. It is considered that existing study being conducted by the Philadelphia District should be implemented to include the program proposed by Mr. Caldwell as it appears to the Delaware River. Following the analysis of the field investigation and preparation of the report on the subject, further consideration could then be given to the need for extending this study. The Philadelphia District will be requested to implement their study to this extent if it is agreeable to the Committee.

/s/ E. B. Conner
E. B. CONNER

C O P Y

CORPS OF ENGINEERS, U. S. ARMY
COMMITTEE ON TIDAL HYDRAULICS

15 January 1965

SUBJECT: Proposal to Develop More Effective Use of Spoil Area

TO: Committee on Tidal Hydraulics

1. Purpose. The purpose of this study is twofold: (1) to evaluate the factors governing residual water content in dredged spoil, and (2) to conclude whether or not reduction of this water content offers a promising method of gaining more effective use of spoil disposal areas.

2. If the study concludes that reduction of moisture content does present a promising improvement, the study could then contain a further recommendation for a project to develop practical means of reducing the water content of spoil disposal areas.

3. Background. The procuring of suitably located spoil disposal areas along a number of our major navigation channels is becoming increasingly difficult and expensive. Partial relief from this condition could be obtained if a greater consolidation of spoil could be obtained by more effective placing and dewatering of the spoil area.

4. A rapid placement of spoil to a considerable depth tends to trap a large amount of pore water which may drain off or evaporate very slowly over a number of years. This pore water may be occupying undue volume. For instance, a water content of 50 percent by volume leaves only 50 percent of solids by volume; thus a reduction to 25 percent in water volume would give a 50 percent increase in spoil storage capacity.

5. Apparently little is known about the moisture content of spoil banks and the rate of their consolidation under various conditions or placement and drainage. Thus, the proposed study must cover a number of factors in order to identify the important variables in spoil bank consolidation.

6. Study Procedure. The study, as proposed, would involve the following steps, some of which could be carried forward concurrently.

Step A. Catalogue of Spoil Areas. Select a "project engineer" and have him prepare a catalogue of spoil areas along our major waterways. This catalogue data would be furnished by the various Districts on a form prepared by the project engineer. The form, among other things, would show data on the historical sequence of placing the spoil in terms of yearly quantities, type of material, method of placement, method of drainage during and after placement, and other factors deemed of interest.

C O P Y

The project engineer could be selective in his search and have the District catalogue only such spoil areas as would probably be of interest, probably obtaining data on not over two or three spoil areas in any one District.

Step B. Literature and Data Search. Concurrent with the preparation of the catalogue data, the Districts would be requested to search their libraries and data files to locate existing factual information dealing quantitatively with the moisture content of new and old spoil banks. Descriptions of these data would be sent to the project engineer.

Step C. Selection of Study Areas. From a review of the available literature and data and the catalogue developed in Steps A and B, the project engineer would then select a number of spoil areas to be studied in further detail. Bearing on these selections would be the degree of completeness of historical data on the placement of the spoil plus the desire to cover a range of placement conditions which are considered as possibly bearing on the degree of consolidation. New and old spoil areas would be included as well as different types (grain sizes) of materials.

Step D. Field Investigations. The field investigations would follow the selections made in Step C and would consist mainly in determining the present bulk density of the spoil areas. The CERC sediment density probe would appear ideally suited for this study. The present density stratification pattern could readily be determined by reading in 2-foot (or greater) vertical increments down into the spoil. Of course in highly consolidated shoals, some ancillary equipment might have to be used to jet the probe to the desired level: in this connection it has been found that the probe can be jettied into place without detectable loss in accuracy if the jetting is properly done. A modest number of samples should be taken of the shoal materials for determination of grain size. It would appear that float-equipped helicopters, swamp buggies, or possibly hovercraft could be used as transport and working platforms in unconsolidated spoil areas.

Step E. Analysis and Report. Based on the analyses of finding from the above steps, a report would be prepared showing:

(1) The relation of rate of vertical placement to rate of consolidation.

(2) The effect of grain size on rate of consolidation

(3) The relation of drainage methods to rate of consolidation.

(4) A conclusion as to whether or not the residual moisture contents of spoil banks are high enough to justify a determined effort to develop methods to gain additional storage capacity by reducing the moisture content of the spoil areas.

C O P Y

7. If a positive conclusion is developed in (4) above, it would then be in order for the report to recommend steps to develop practical methods for improved spoil disposal practices toward the end of obtaining faster and more complete consolidation of dredge spoil.

8. Estimates of Cost. Steps, A, B, C, and E, as outlined above are estimated to cost a total of $10,000; this assumes that the Districts would furnish the data requested in Steps A and B at no cost to this project.

9. The cost of field surveys (Step D) would be related approximately to the number of spoil banks studied. The required probing and sampling equipment could probably be mobilized for less than $10,000. A float-equipped helicopter could be rented for about $700.00 per day; then allowing three days of rental per spoil area studied, the rental per spoil area would be $2,100.00. A 3-man survey crew (project engineer, electronic technician, and helper) to work with the helicopter would cost some $150.00 per day, including per diem; allowing 5 days per spoil area, the survey crew costs would be $750.00 per spoil area. Assuming that eight spoil areas were studies, the field costs are estimated to be as follows:

Mobilization of equipment	$10,000
Helicopter rental (24 days @ $700.00/day	16,800
Field crew for 8 locations (8 weeks at $510/wk.)	4,080
Field crew travel expenses	
Travel	1,000
Per Diem	2,680
Pickup truck, (8 weeks @ $90/week)	720
Laboratory analyses	
Grain size analysis on 240 samples	500
Total for field work	$35,780

10. From the above, it is seen that the estimated costs would be as follows:

Steps A, B, C, and E (office work)	$10,000
Step D (field work and sample analyses)	35,780
Estimated project costs	$45,780

11. It is believed that the importance of gaining an understanding of this subject justifies the expenditure of $45,780 as outlined above. I accordingly recommend that funds be allocated for the undertaking of this study.

/s/ Joseph M. Caldwell
JOSEPH M. CALDWELL
Member
Committee on Tidal Hydraulics

APPENDIX E-II

FIELD AND LABORATORY TEST DATA

I. The scope and general results of the soil testing program were discussed in Sections 4, 5 and 6 of this report. Further details are given in the following paragraphs.

II. PROCEDURES.

All laboratory tests were conducted according to procedures in EM 1110-2-1906, "Laboratory Soils Testing." Vane shear tests were performed in the boreholes using an Acker vane shear device with 3-5/8 by 6-inch vanes. In making the tests the vane was advanced 18 inches below the bottom of the hole and rotated at a speed of 6 degrees per minute.

III. RESULTS.

The physical properties, water content, density, plasticity, and shear strength, are plotted on the individual boring logs on plate 19 through 25. Plates 26 and 27 contain summaries of detailed test data and individual test reports are shown on plates 28 through 36.

IV. Shear strength at natural water content was determined by vane shear testing in the boreholes with check testing by unconsolidated-undrained "Q"-type triaxial compression tests on 1.4 inch diameter specimens. The resulting strengths were in the range usually found in the vicinity of the Delaware River for the type of material present. Comparison of the two methods shows that the vane shear results are generally lower than those for the triaxial "Q" tests which is opposite to the usual relation in Delaware River tidal marshes. The reason for this reverse relationship is not known, although in a few cases the vane results are too low to be considered accurate and it appears that the material may have been disturbed.

V. Consolidated-undrained triaxial compression tests ("R" tests) were also performed using 1.4 inch diameter specimens. These tests indicate friction angles of 12 to 16 degrees and cohesion values of 0.05 to 0.3 tons per square foot for total stresses and friction angles of 30 to 39 degrees for effective stresses. The results for total stresses are in the range commonly found for natural organic silts in the region. The friction angles for effective stresses in the "R" tests, determined from measurement of pore pressure, appear somewhat high and the variations from 30 to 39 degrees do not show a consistent relation to other physical properties, such as decreasing plasticity. The results of these tests, used to evaluate increased shearing resistance and allowable bearing pressure with consolidation of the spoil under load, should therefore be conservatively interpreted and applied.

APPENDIX F

DISPOSAL AREA DIKING IN WATER

TABLE OF CONTENTS

I. INTRODUCTION.

The purpose of this report is to present the history of development, general principles and criteria for design of disposal areas on or adjacent to tidal flats bordering the Delaware River from Trenton to the Sea. It is not intended for use as a design manual, but as a guide to assist in the planning and design of diking to be used for disposal areas in this environment. This report was written by Mr. B.L. Uibel, P.E., under the general guidance of Mr. E.L. Dodson, P.E., both of the Engineering Division of the Philadelphia District Office.

II. HISTORY ON DELAWARE RIVER DIKING.

Dikes have been constructed in the Delaware River and its tributaries for many years. The early settlers built many miles of dikes to reclaim marsh land from flooding by high tides. Their principal objective was farming. These generally, were mud banks which frequently were protected by a stone face protection.

Over the years many banks have been built by upland owners to improve and protect their real estate at the rivers edge. For the greatest part these were banks built above high tide and had protective stone placed on their outer faces. This protection was usually in the form of riprap although in some instances it was provided by stone walls.

In the early 20th century the Government developed disposal areas for the receipt of dredged spoil from the enlargement and maintenance of navigation channels. Large riparian areas were developed into disposal areas. Amongst these were the areas known as Artificial Island, Killcohook, Edgemoor, and Hog Island. These areas now represent fast land well above the effect of any tide.

Artificial Island has now become the site of the new 2,000,000 KW nuclear power plant; dredged spoil has provided much of the land for Philadelphia International Airport and the industrial and commercial complex *in that vicinity*.

The dikes with stone protection that were installed by the Government in the early 20th century to contain disposal areas were outstandingly successful. No significant maintenance has been required on these structures and failures have been minimal. They continue to perform their function to the present time. They continue to remain and hold a stable shore line even while fills which reach to forty feet have been created behind them. The success of these structures is no doubt related to the slow rate of fill over the years and to the stone protection provided.

Many of these areas, particularly those downstream of Philadelphia, required the construction of dikes on foundations consisting of deep deposits of soft silts and clays. Various methods were used in the construction of dikes on such foundations. Edgemoor Disposal Area was developed in part by the periodic dumping of coarse materials from dredging operations at various points along the river. These materials were usually transported from the dredging areas to Edgemoor in scows and dumped along the alignment of the outer dike. In time, the foundation of the dike was established and the dike was eventually raised to its present height in a number of construction increments. Other areas have been developed by establishing a dike base by free discharge of material from pipeline dredges along an established alignment. These pumped materials eventually built up along these alignments and were raised to an elevation above Mean High Water either by continuing the pumping or reworking the upper portions of the

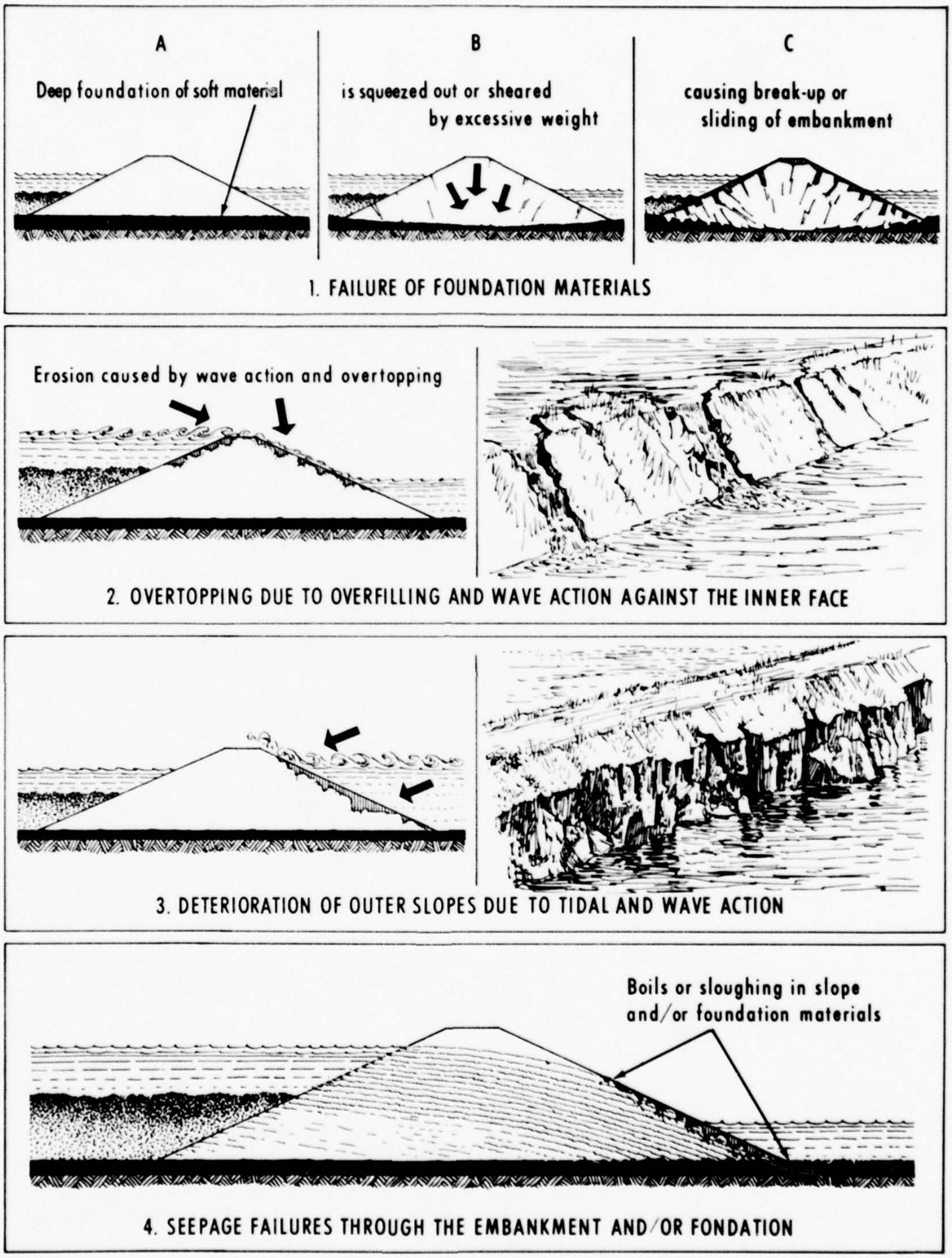
dike with other types of equipment. Another type of construction used during the early 20th century placed an emphasis on the use of timber and stone. These structures were used for the first stages of the Killcohook and Artificial Island Disposal Areas and consisted of a two-row pile and timber bulkhead construction with rock protection on the outside of the bulkhead. Materials, usually of a granular nature, were pumped inside of these bulkheads to form the dike section. This method is in direct contrast to today's practice where massive quantities of soil are relied upon to form a stable structure. The contrast is a manifestation of changing technology. The timber and stone required more hand labor and a lesser mass of material than current practice. Current practice frequently favors big bank sections as it is comparatively easier and less expensive to do this with the large dredges and large earth-moving equipment now available, than to provide the detailed construction of timber and stone. In fact, with the current ability to handle larger masses of earth cheaply the need for riprap protection can frequently be eliminated where river condition and materials permit. The riprap is eliminated by placing a quantity of fill sufficient to provide a flat beach for run up of the water front. This is discussed in more detail elsewhere in this report.

Detailed accounts of problems encountered in the initial development of older disposal areas have not been uncovered in the cursory file search made in conjunction with this report. However, according to the memory of District employees connected with this work as far back as 1925, major failures of dike sections have been relatively uncommon occurrences. Where such failures did occur it is generally agreed that the failures could be attributed to one or a combination of the following:

1. Failure of foundation materials;
2. Overtopping of dikes due to overfilling of the disposal area and/or wave action against the inner face of the dike;
3. Deterioration of the outer slopes of the dikes due to tidal and wave action;
4. Seepage failures through the embankment and/or foundation. Graphic illustrations of these modes of failure are shown on Figure 7.

In some cases, poorly conceived remedial action for impending failure has contributed to the magnitude of failure. One of the more common remedial actions attempted to stabilize a bank failure occurring during construction has been to add additional fill to the failing section in an effort to "reach hard bottom." In cases where this "hard bottom" was overlain by extensive deposits of weak materials, this effort resulted in enlargement of the failure zone due to the additional overloading. In other cases, remedial actions, which would have a major effect upon operations (such as halting dredging operations at the first signs of weakness in a bank section) were delayed, while other less drastic methods were employed in an effort to stabilize the bank. This occasionally resulted in failures due to the resulting "too little -- too late" policy.

It is difficult to evaluate the economics of these actions, since there have no doubt been many cases where such methods have met with success at considerable savings in contract or hired labor time and expense. It is evident, however, that the best method of preventing the use of such incorrect methods is the maintenance of continually open and rapidly reacting channel of communication and cooperation between design and operating personnel. In addition to this, where dikes are constructed on weak foundations or of questionable embankment materials, or



HISTORIC CAUSES OF DIKE FAILURE

Figure 7

both, daily or more frequent inspections of dikes during construction and filling operations by qualified technicians and/or engineers go far toward insuring early diagnosis of imminent failures and may provide additional time for the determination and execution of the best corrective action.

III. TYPES OF DISPOSAL AREA DIKES EMPLOYED BY THE PHILADELPHIA DISTRICT.

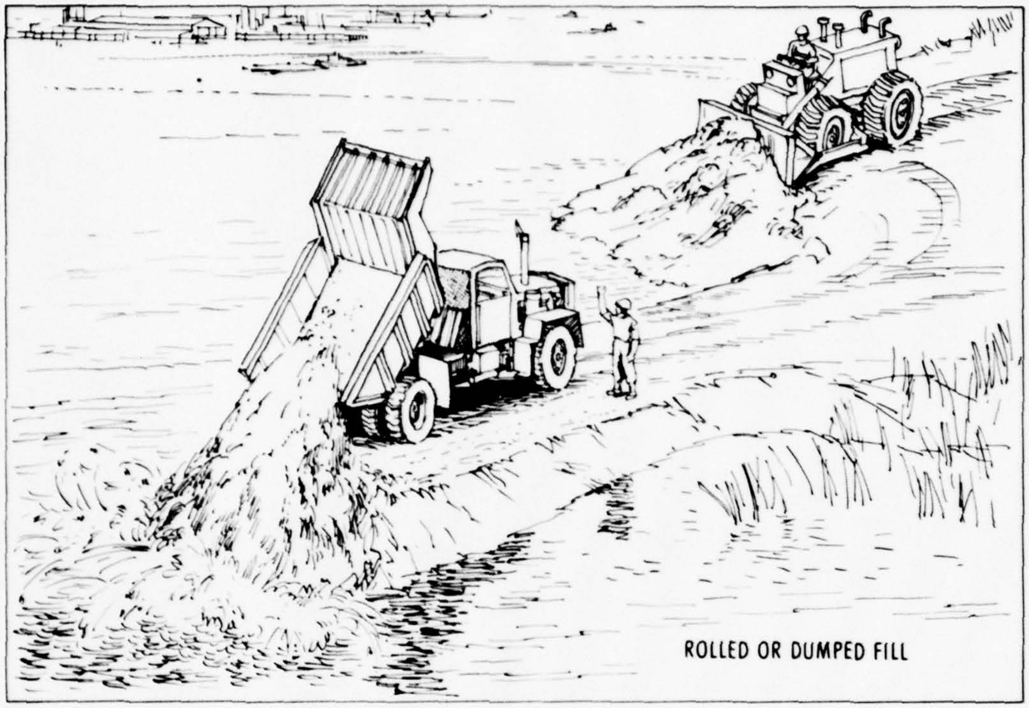
The objective of dike design for disposal area is to arrive at a dike which will safely and permanently retain the dredged material at the most economical cost. Of considerable importance to accomplishing this end result is a knowledge of the available materials in the area for diking so economics of material source and method of construction can be evaluated. It is also necessary to consider the rate of anticipated filling of the area to evaluate the merits or possibilities of stage construction. The types of dikes generally used are discussed below.

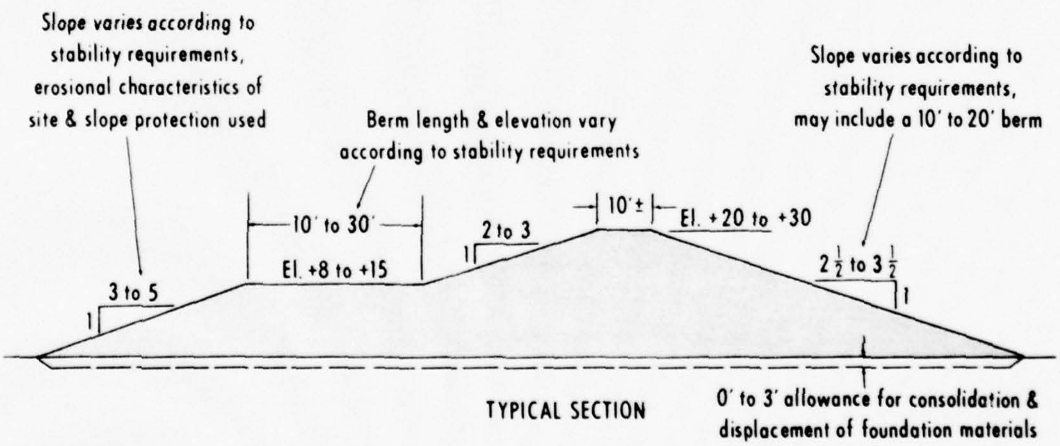
Rolled or Dumped Fill. This type of dike is employed where a land borrow source of acceptable quality is available within reasonable hauling distance of the site. The allowable haul distance is determined by the comparable cost of other methods of construction from other borrow sources. The type of material best suited for this type of construction is a sandy gravelly material with trace to some fine binder. However, less than ideal borrow materials are often used and provide adequate diking if properly designed. Below the MHW line, materials containing a trace or no fines are preferable, since wave and water action tends to carry fines away, undercutting the slope and contributing to turbidity and shoaling in the river.

The normal method of construction for the rolled or dumped fill dike is to begin the construction on solid ground and extend it into the water by end dumping from trucks until the dike has reached an elevation above MHW. The dike is then extended employing that section already constructed as the haul road. Materials placed above MHW may be compacted, if required, for stability. This type of dike construction usually requires a dike section with berm or berms in order to provide stability over the poor foundation materials normally found in the tidal flats. Figure 8 illustrates this method of construction and dike section usually employed.

Hydraulic Fill. As a general rule, the ideal situation for construction of a disposal area in the water is that in which suitable granular borrow material for a hydraulic fill dike is encountered inside the disposal area. This allows the construction of a hydraulic fill dike section from a borrow area close to the dike alignment and as a bonus, provides additional disposal area volume as a result of the removal of borrow from inside the area. In other cases, the scarcity of land borrow and the requirement of a large volume dike section, because of poor foundation conditions, makes the use of a subaqueous borrow source outside the disposal area limits the most economical design available. Materials for hydraulic borrow should be sands and/or gravels with little to some fines. The greater the amount of fines in the borrow material, the higher the overpumping ratio required. As a general rule, borrow materials containing an excess of fifteen per cent fines are not considered suitable for hydraulic fill in areas where the fine material which flows away from the discharge point will contribute to stream pollution or channel shoaling.

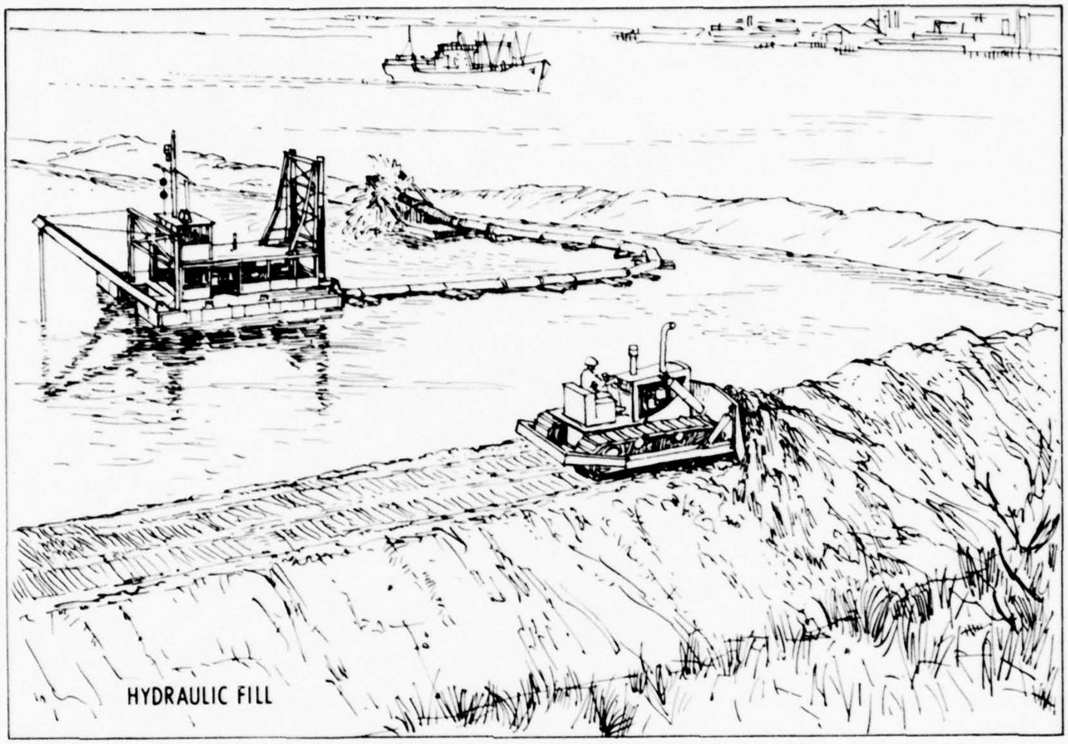
The method of construction em-

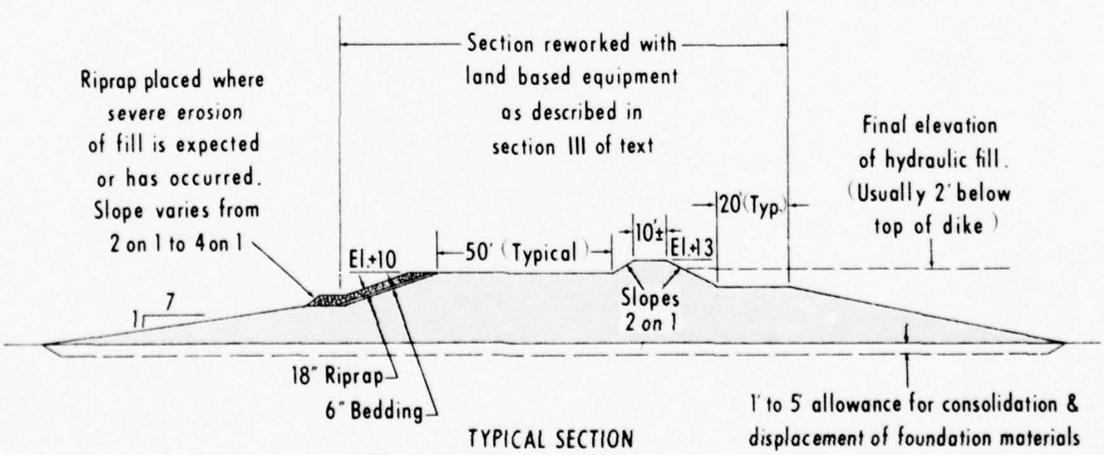




CONSTRUCTION BY LAND BASED EQUIPMENT

Figure 8





TYPICAL SECTION

Foundation composed of deep section of soft silt, clay and/or peat and may be stratified with layers of sand

CONSTRUCTION BY PIPELINE DREDGE AND DOZER

Figure 9

ployed in constructing a dike of hydraulic fill is to place the material into the dike section hydraulically to a level above MHW. When sufficient material has been placed along the alignment in this manner, it may be desirable to rework this material with land based equipment to provide the most economical dike section to the design elevation. See Figure 9 for an illustration of this method.

Dragline Fill. When materials suitable for dike construction are available along the dike alignment, dike construction by barge mounted dragline is often the most economical method of construction. The best material for this construction are sands and gravels, although silty and clayey sands are often used. Numerous instances of dikes constructed with other materials (i.e., organic silts and clays, fine sandy silts, etc.) are present on disposal areas constructed by both public and private organizations. The latter practice is not recommended unless the circumstances surrounding an individual project require this type of borrow use. Normally, the borrow areas must be located to allow borrowing from within the disposal area.

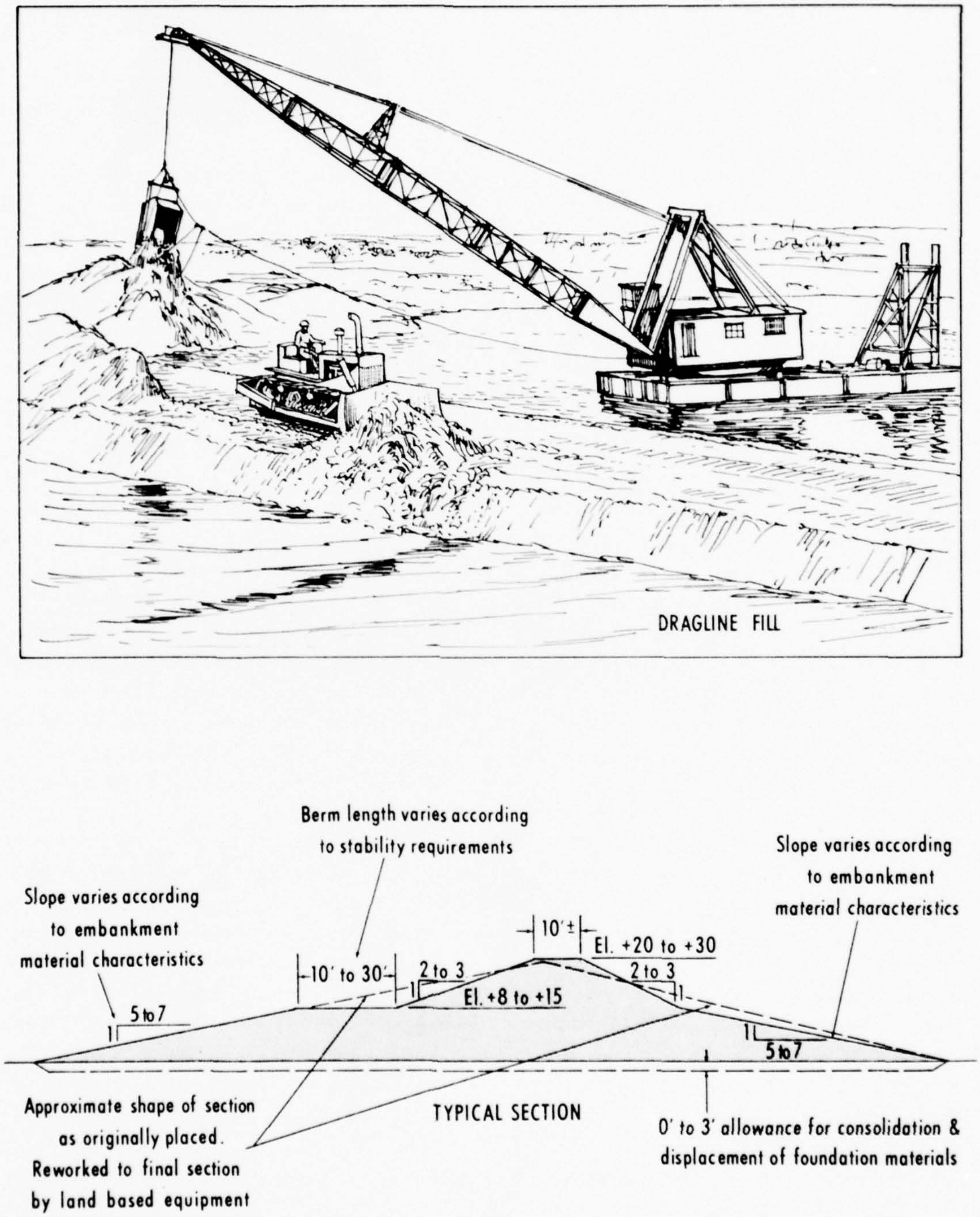
The normal method of construction is a cut and fill operation employing large capacity dragline equipment as shown on Figure 10. The dike section obtained usually has flat slopes of about 5:1. The dike fill is brought to an elevation above MHW and may be reworked with land based equipment above this elevation to provide the final design section. The success of this type construction is dependent on having a foundation material which is firm enough to prevent squeezing of the foundation material into the excavation being made by the dragline. The length of dragline boom required for this type construction is a limiting factor, the boom length being dependent on the angle of repose of the material and the height required to get the bucket above dike level.

IV. SUBSURFACE EXPLORATIONS AND SOILS TESTS.

Subsurface explorations for disposal areas are performed to determine the foundation conditions and available borrow sources. Spacing of borings are generally no more than 1,000 feet along the dike alignment and normally a 500-foot spacing is maintained. This spacing is closed when heterogeneous foundation conditions are encountered to insure a thorough knowledge of the foundation conditions. Generally, these borings are taken to a depth no less than the height of dike. Borrow investigations are sufficient to provide information concerning the areal extent, depth and quality of available borrow materials. This is generally accomplished with a grid pattern in the borrow area with a spacing of from 200 feet to 400 feet. The borrow investigations are taken to just below the proposed depth of borrow which will be determined by the type of borrow operation to be employed.

Ideally, a phased program of subsurface explorations is employed. The first phase consists of a general coverage of the foundation and borrow areas to enable the designer to determine a preliminary dike design and the probable borrow source. This program usually comprises about 50 per cent of the total exploration effort. The second phase of explorations provides detailed information on foundation conditions along the final dike alignment and a more complete investigation of the borrow source or sources.

Sampling and testing performed in the field consist of disturbed and undisturbed sampling and vane shear testing,



CONSTRUCTION BY BARGE-MOUNTED DRAGLINE

Figure 10

usually in drive borings. Every effort is made to obtain undisturbed samples and vane shear tests in all critical materials in the foundation. Borrow explorations are confined to disturbed samples from drive borings and in some cases from test pit operations.

Soil tests performed consist of moisture content and identification tests on disturbed samples vane shear tests of the *insitsu material, triaxial shear tests* (Q, R, & S), and consolidation testing on undisturbed samples. The last three types of tests are generally limited to the foundation materials to determine design values. Usually, the design values for the embankment materials are based on conservative estimates and not on test data, since the embankment material strengths are not usually critical in the dike design.

V. DESIGN CRITERIA.

*Design procedure for design of dis*posal area diking has evolved from a combination of experience from past successes and failures and standard soil mechanics design procedures. The design procedure has necessitated the adoption of design criteria based on judgment, since established design criteria in general use is not directly applicable to disposal area dike design.

Disposal area diking is designed to meet the following criteria so that these areas will be reasonably safe and stable during all phases of construction and operation.

1. The slopes of the dike must be stable under all reasonably foreseeable conditions of the construction and operation, including rapid drawdown on the outer slopes where exposed to tidal conditions.

2. The embankment must be designed so as not to impose any excessive stresses upon the foundation (except for planned displacement of very soft materials in the upper zone of the foundation).

3. The passage of seepage flow from the inner to outer slopes must be controlled to prevent sloughing of the outer slopes.

4. The freeboard must be great enough to prevent overtopping of the dike by waves from either side of the dike.

VI. SELECTION OF DIKE SECTION.

The selection of dike section is dependent upon the foundation conditions, the type of borrow available for diking material, the *contemplated construction* method, and the proposed filling rate of the disposal area. The dike section design required for stability is determined by standard methods of slope design, principally the Swedish arc method, and where applicable, the sliding wedge analysis. The *cases investigated* are the as-constructed, rapid drawdown and steady seepage cases employing the proper design strengths for each type of analysis.

Where foundation materials are deep deposits of clays and silts, as is frequently the case, consolidation is very slow and one of the design assumptions for stability assumes a seepage condition through the dike from retained dredged material and an unconsolidated foundation (Q Strength). Safety factors adopted for design are 1.2 which are below the criteria cited in EM 1110-2-1902, "Stability of Earth and Rockfill Dams." These design safety factors were derived from a correlation of actual experience with design methods.

The borrow location and quality determines in most cases the method of construction to be used and the steepest slope of the embankment section that can be considered. When the borrow source is

located under water, requiring the use of dragline or hydraulic fill diking, the embankment slopes, as placed, will vary from 5:1 to 8:1. The upper portions of these slopes may be reworked to steeper slopes if the foundation conditions and material savings make such an operation desirable. For most land borrow sources, the rolled or dumped fill method of dike construction is used with embankment slopes of from 2½:1 to 3½:1 with berms, depending on foundation conditions.

Foundation conditions in most areas where disposal diking is to be constructed in water on river bottom deposits can generally be classified as poor to fair. In many cases, a substantial savings can be effected by careful siting of the dike alignment, taking full advantage of the most favorable foundation conditions available on the site. The weakness of the foundation materials generally encountered at disposal area sites in tidal flats, particularly in the upper 10 to 20 feet of the foundation, usually requires the construction of a wide based dike section. This is generally accomplished by the use of a bermed section, although in some hydraulic and dragline fill sections the slope assumed by the embankment fill during construction will provide a base section wide enough to satisfy stability requirements without need for extra base width. A displacement and consolidation allowance for the upper zone of foundation materials is generally allowed in the design and frequently ranges from 1 to 5 feet. This allowance is based principally on the depth of very soft materials encountered in the uppermost zone of the foundation and the assumption that the major portion of this very soft zone will be displaced laterally by the embankment materials as they are placed.

Where the proposed rate of filling of the disposal area is relatively slow (from 1 to 3 feet per year) substantial savings in the dike section is often realized by employing incremental dike construction. This method includes initial construction of a low dike section to an elevation several feet above MHW (top elevation generally from +10 to +15). When the disposal area has been filled to a point from 2 to 4 feet below the top elevation of this initial construction, a second stage is constructed (usually between 2 and 4 feet high) to enable the further filling of the disposal area. This staging is then continued as required until the final disposal area elevation is reached. In most cases, where this construction method is employed, a second program of exploration and slope design should be performed when the initial stage of disposal area filling has been completed. This may permit steepening the overall slope of the embankment because of strength gains in the foundation material due to the consolidation of these materials during the initial stage of development. The most economical material for use for the incremental diking usually is the materials adjacent to the dike on the inside of the disposal area. This material is frequently extremely wet and dries very slowly in place. To expedite drying, the material is removed from the disposal area by dragline and deposited on the top of dike or an outside berm, where it is permitted to dry before being moved into final position. If possible, this method of construction should be combined with a method of filling of the disposal area requiring the discharge of dredged materials along the inside of the dikes. This will usually provide a better source of diking materials immediately adjacent to the dikes and may provide a source of material

which does not require drying before use in the incremental diking, thereby doing away with the requirement for double handling of this material as well as provide better base material for the dike increments.

Normally, the final choice of the dike section is based upon an economic analysis of two or more proposed designs. If more than one source of diking material is available, a design is made on using each source available and an economic analysis made for each design. In some cases, a comparison is made for construction of the dike to its full height as compared to an incremental method of diking.

VII. SLOPE PROTECTION.

The two most commonly employed methods of slope protection are armored protection consisting of riprap and provision of beaches to the river side of the dikes. Examples of both types of protection are shown on Figure 11.

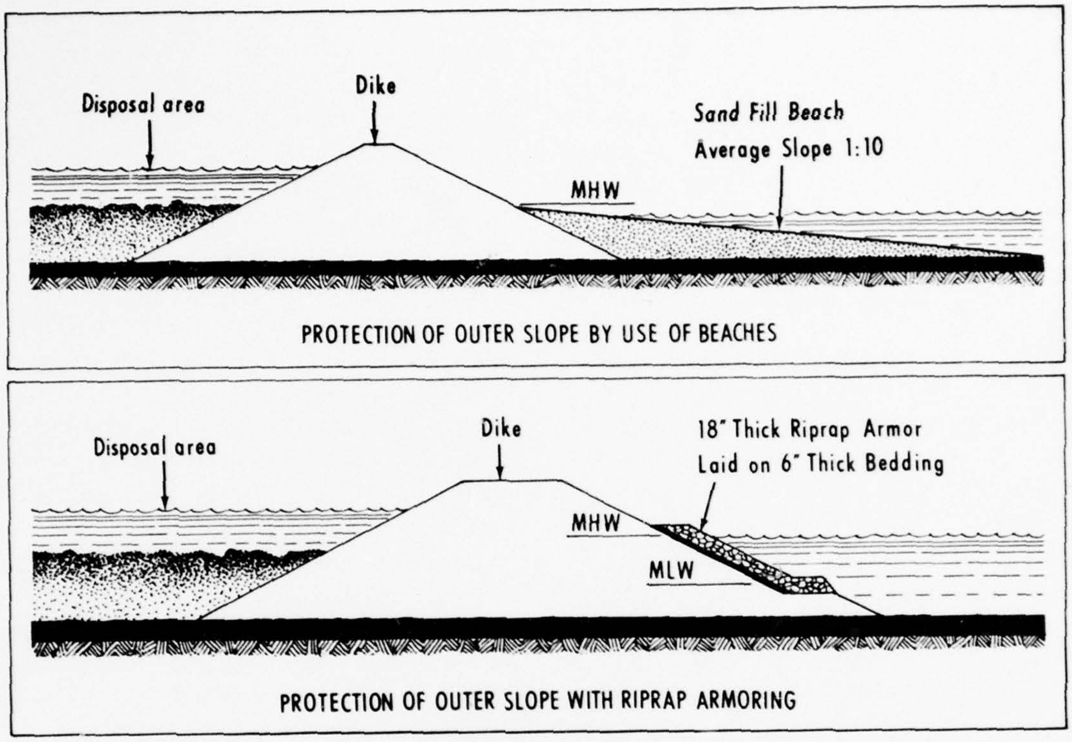
In many areas armored protection is required for diking to prevent excessive erosion of the dikes due to wave action. Erosion of the dikes must be controlled to preserve stability of the dike in most cases and to prevent the displacement of dike and dredged material into the estuary and ultimately into a shaol. This armoring normally extends from a point several feet below mean low water to an elevation several feet above mean high water. In all but the exceptional circumstances, a blanket of bedding material must be placed under the riprap to prevent loss of the underlying embankment material through the riprap due to wave action. The extent of the riprap zone is dependent upon the amount of wave force to which the slope will be subjected during the most extreme weather conditions which can be expected at the site.

Riprap size and thickness is determined from conventional design methods given in EM 1110-2-2300, "Earth Embankments", the major controlling factor being the design wave height.

Bedding materials are normally designed so that the maximum grain size of the bedding is large enough to prevent the filter from washing out between the stones of the riprap, but is not of sufficient size to produce segregation of the bedding layer during placement.

Beaches provide another means of slope protection against wave action where the dike material is essentially granular in nature. The use of a beach slope in lieu of riprap is frequently the most economical solution, particularly where foundation conditions require flat dike slopes and/or where the logical source of material for dikes is dredged in-place fill. It was reasoned that if the relationship between a stable beach slope and material gradation could be discovered from actual conditions, this relationship could be used with considerable confidence in future designs and economic comparisons of beach slopes and riprap.

Investigations of existing beaches at various points along the Delaware River were made during 1967 and 1968 to evaluate the relationship between beach slope and size of material on the beach surfaces. These investigations included surveys to establish beach profiles, sampling of beach materials at the high and low water levels along these profiles, and gradational analysis of these samples. The gradation data is summarized on Plates 1 through 4. The desired relationship between beach slope and gradation was not evident. This might be attributed to other factors, which influence the beach slope, such as location and probability of wave attack, or it might



PROTECTION OF OUTER SLOPE BY USE OF BEACHES

PROTECTION OF OUTER SLOPE WITH RIPRAP ARMORING

SLOPE PROTECTION

Figure 11

be the result of high and low water samples not being truly representative of the beach material.

The following was concluded from the investigations:

1. Beach slopes measured from HWL to LWL ranged from 1:5 to 1:20 with an average value between 1:10 and 1:15.

2. Beach materials present on beaches downstream of Delaware Memorial Bridge consisted primarily of a uniformly graded fine to medium sand with a trace (5 to 12 per cent by weight) to no fines. It would appear that materials with D_{85} 1mm; D_{50} 0.70mm; D_{15} 0.30mm and less than 5 per cent passing the #200 mesh screen (0.074mm) will provide a suitable material for beach fills in this area.

3. Beach materials present on beaches upstream of the Delaware Memorial Bridge to the Pennsylvania-New Jersey Turnpike Bridge were found to be composed of a wide range of materials. The materials ranged from gravelly sands and sandy gravels down to fine to medium sands with a trace of silt. No consistent pattern of beach material gradation is indicated from this portion of the investigation.

Based on the above findings the following recommendations were made for the design of beaches fronting dikes constructed along the river:

1. Each design should be based upon a study of existing beaches in the immediate vicinity of the proposed diking. In particular, those beaches in the area having similar controlling conditions, such as, distance from the ship channel, fetch distance, water depth and total channel section, as the proposed dike should be

investigated to develop the design of the new beach.

2. For preliminary design purposes, an overall beach slope (from HWL to LWL) of 1:10 should provide sufficient material for the establishment of a stable beach along the reach investigated.

3. In areas susceptible to high rates of dike erosion, comparative studies of full or partial riprapping of the dike in place of or in combination with a section employing beaches should be made to determine the most economical design for the project.

VIII. CONCLUSIONS.

Design of disposal area dikes is intimately related to the most economical construction methods and type of material available. Dikes in tidal flats persistently encounter foundation conditions, which are extremely difficult to investigate and test; thus, the theoretical design procedures must be tempered with considerable judgments based on experience and past dike performance under similar conditions. As disposal areas are forced more into areas of poorer foundations by completion of more desirable areas, it becomes increasingly important to design dikes using long range planning principles rather than relying on each contractor to satisfy only requirements for his contract.

APPENDIX G

RIPARIAN SOURCES OF DIKING IN WATER

TABLE OF CONTENTS

I. FOREWARD AND SCOPE OF INVESTIGATIONS.

The quantitative and qualitative analysis and estimates of various types of materials occurring beneath the Delaware River, as shown in Plate 41, was made by the Geology Section, Foundations and Materials Branch, Engineering Division, Philadelphia District. These data were compiled from logs of test pits and borings and from results of a geophysical survey, all made in connection with various disposal area and channel dimension studies. In areas downstream of Reedy Island dike the evaluation of materials was based solely on literature research, U.S.C. & G. chart markings and the aforementioned geophysical survey performed by the firm of Edgerton, Germeshausen and Greier, Inc., of Bedford, Mass. for the Philadelphia District in 1966 under contract DA-36-109-CIVENG-66-81. Sources of material indicated are general and detail investigation of probable areas noted herein would be necessary for a specific use of material. This appendix was written by Mr. A.J. Depman, CPG, under the supervision of Mr. E.L. Dodson, P.E., Chief, Foundations and Materials Branch.

II. TYPES OF MATERIALS CONSIDERED.

The primary purpose of the investigations was to locate and attempt to determine the extent and thickness of various types of extractable materials occurring in Delaware River, which possibly can be utilized in the construction of disposal area dikes. These materials are classified generally as: (a) Recent and Pleistocene granular deposits; (b) Cretaceous sands and clays, and (c) bedrock.

a. Recent and Pleistocene granular deposits consist of sand, gravel and cobble accumulations occurring as shallow lenticular deposits or as thicker, channel-like deposits occupying pre-existing Pleistocene courses of the Delaware and tributary streams. These deposits are considered as sources of excellent dike-building materials, and as such, are also valuable and desirable as sources of construction materials (select borrow) by general contractors, commercial sand and gravel producers, etc.

b. Cretaceous sands and clays are *not* as desirable as (a) above; however, these stiff, dense deposits can be used in dike construction. The utilization of these deposits for such purposes are predicated on their availability from required channel or anchorage excavation.

c. Bedrock consisting of mica schist, mica gneiss, gabbroic-types and some granites would be utilized, as (b) above, where required excavation would provide quantities sufficient for use as diking material or as riprap facing for dikes constructed otherwise.

III. METHOD OF USAGE IN DIKE CONSTRUCTION.

The materials noted above, with the exception of bedrock, can be removed from the river bottom by conventional hydraulic dredging methods. Placement of such materials into dikes can be made directly from pipelines or by rehandling after placement into a disposal area. Bedrock removal is facilitated by blasting and use of a dipper dredge or dragline. Transportation from the site is normally accomplished using bottom-dump scows and placement is made in a rehandling basin. Where used in dike construction, rock products are normally placed in the dike alignment by means of dragline or clamshell bucket directly from flat-deck scows.

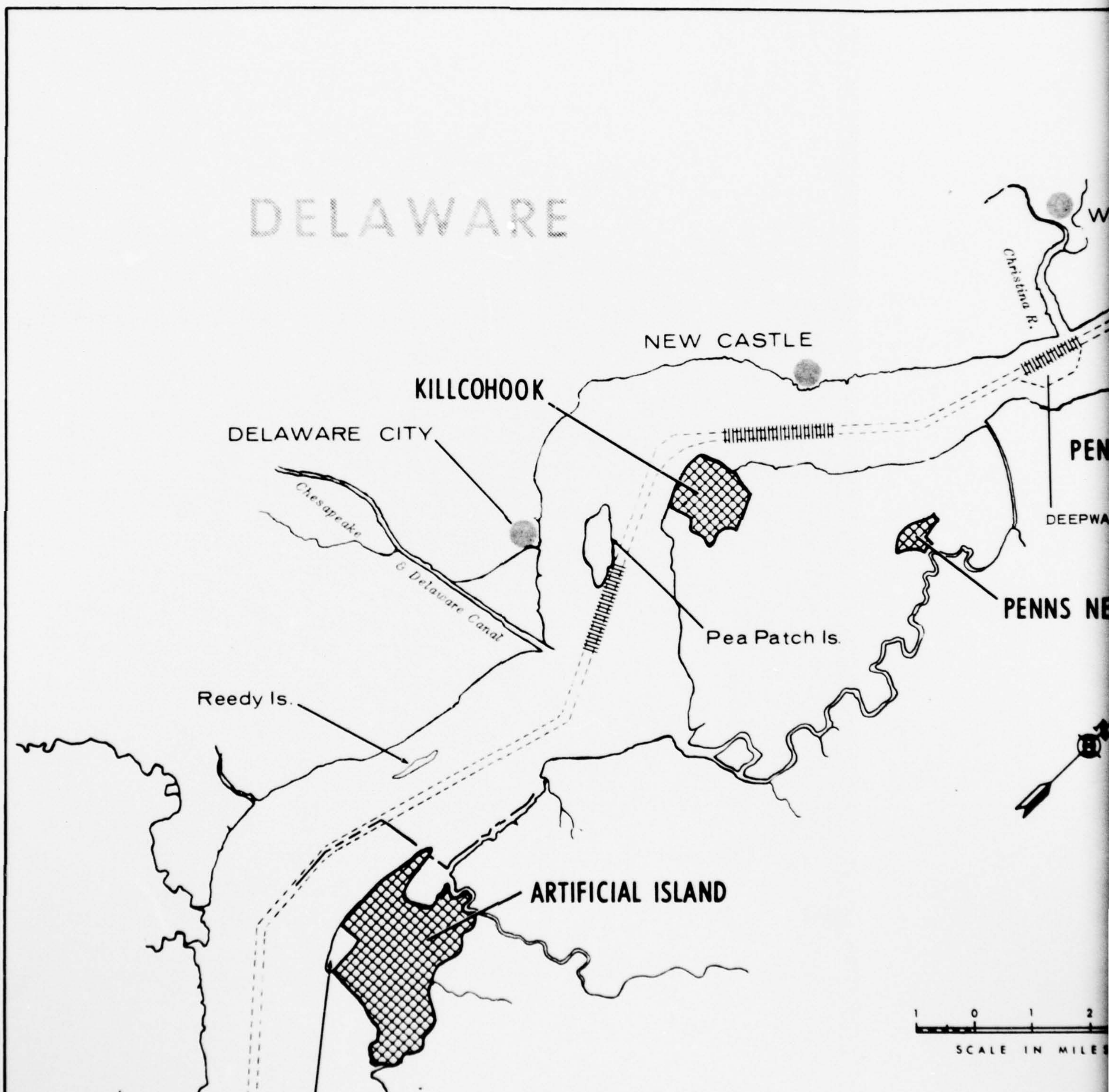
IV. RECOMMENDED FUTURE INVESTIGATIONS.

In order to provide more detailed data and to better analyze the extent of usable construction materials in Delaware River the following program of future investigation is recommended:

a. Expand on dimensions of known granular deposits by means of geophysical surveys similar to those used in the channel dimensions study in 1966. Similarly, such methods should be employed in suspected and known bedrock areas.

b. Make maximum use of jet probes and test pits in determining thickness, quality and character of granular deposits as well as definition of the buried bedrock surface.

c. Use borings only to define the character of bedrock (to at least 60 feet below river datum) and Cretaceous sand and clay deposits as required in future channel and anchorage dimension studies.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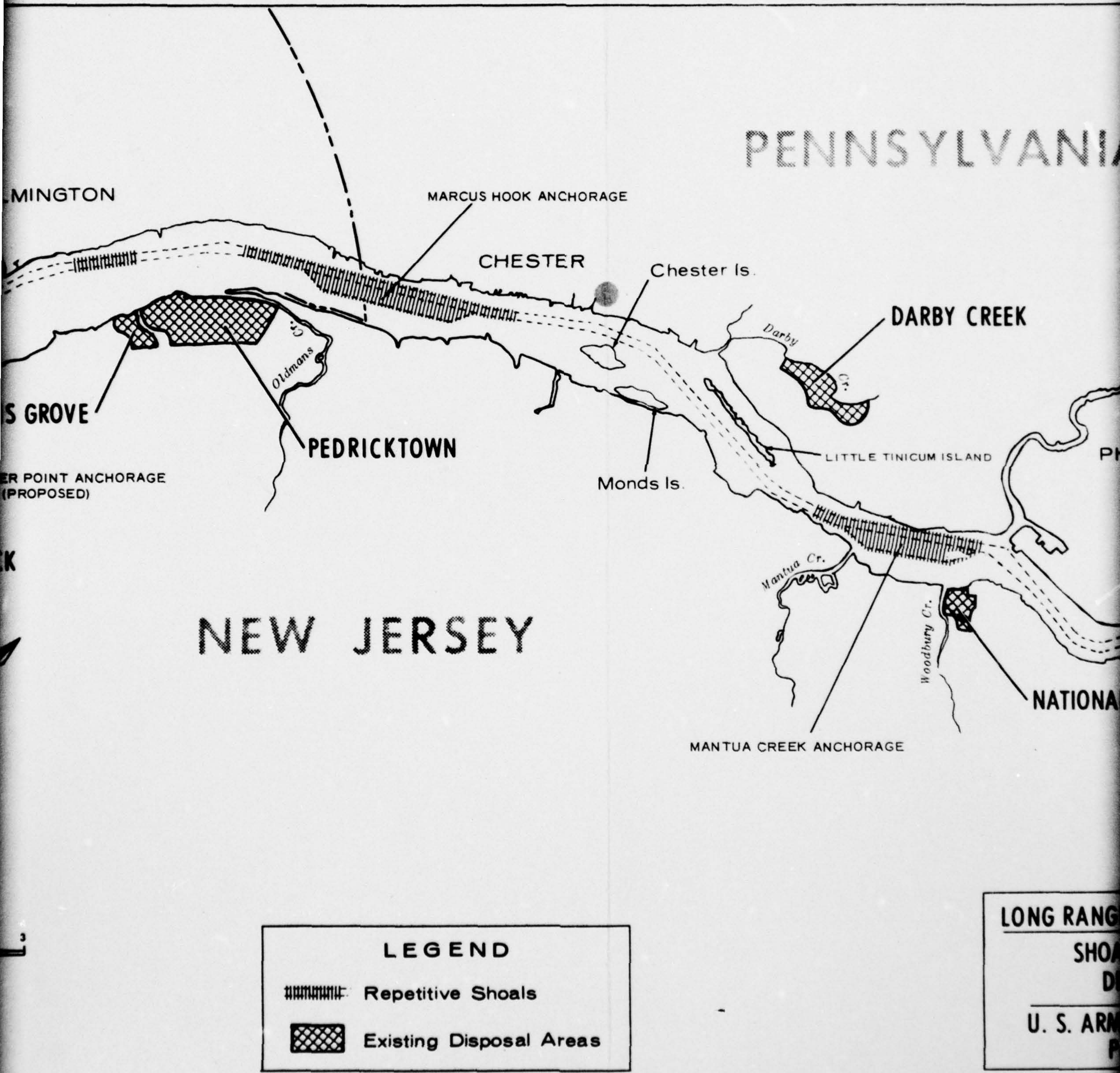
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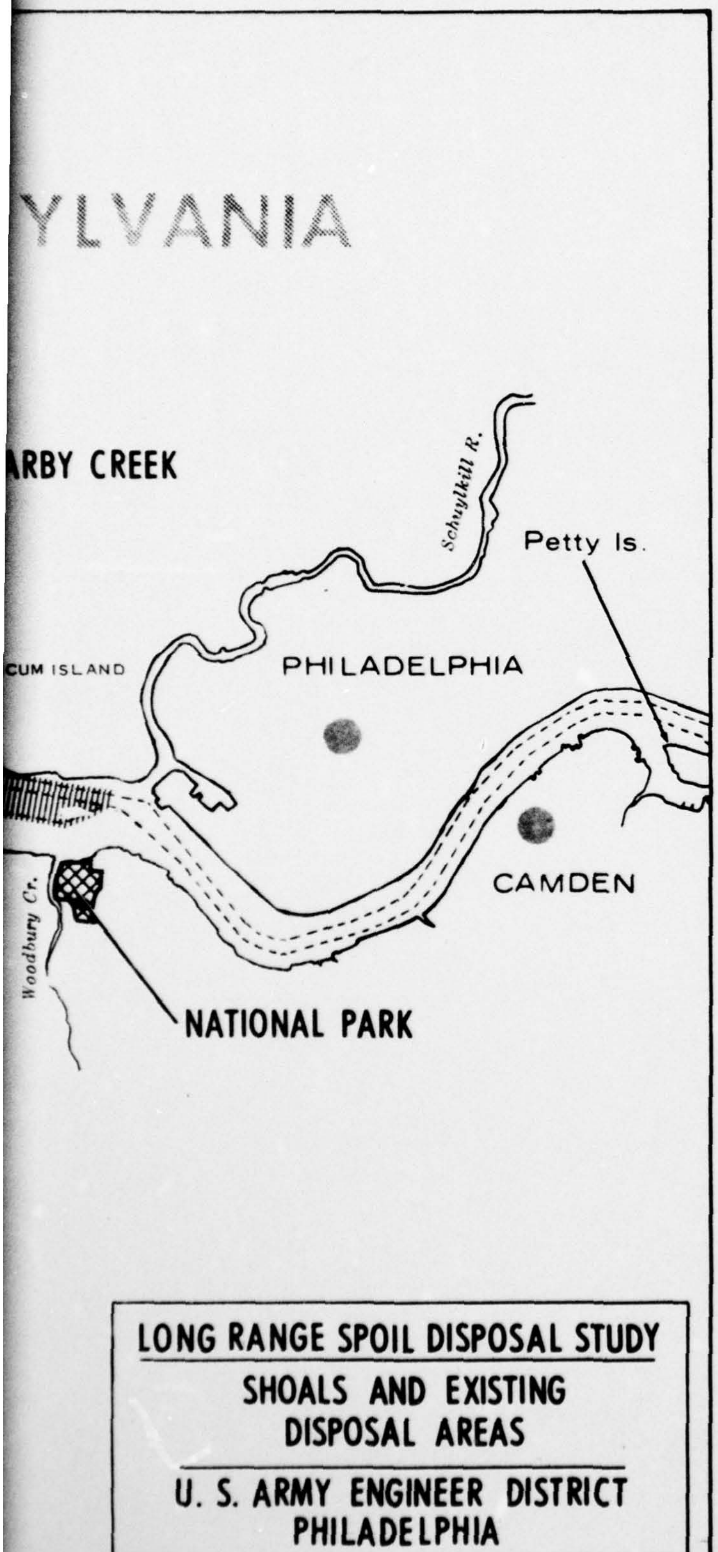
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LONG RANGE SPOIL DISPOSAL STUDY
SHOALS AND EXISTING
DISPOSAL AREAS
U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

1 3 PLATE 1

MAINTENANCE DREDGING REQUIREMENT FOR DELAWARE

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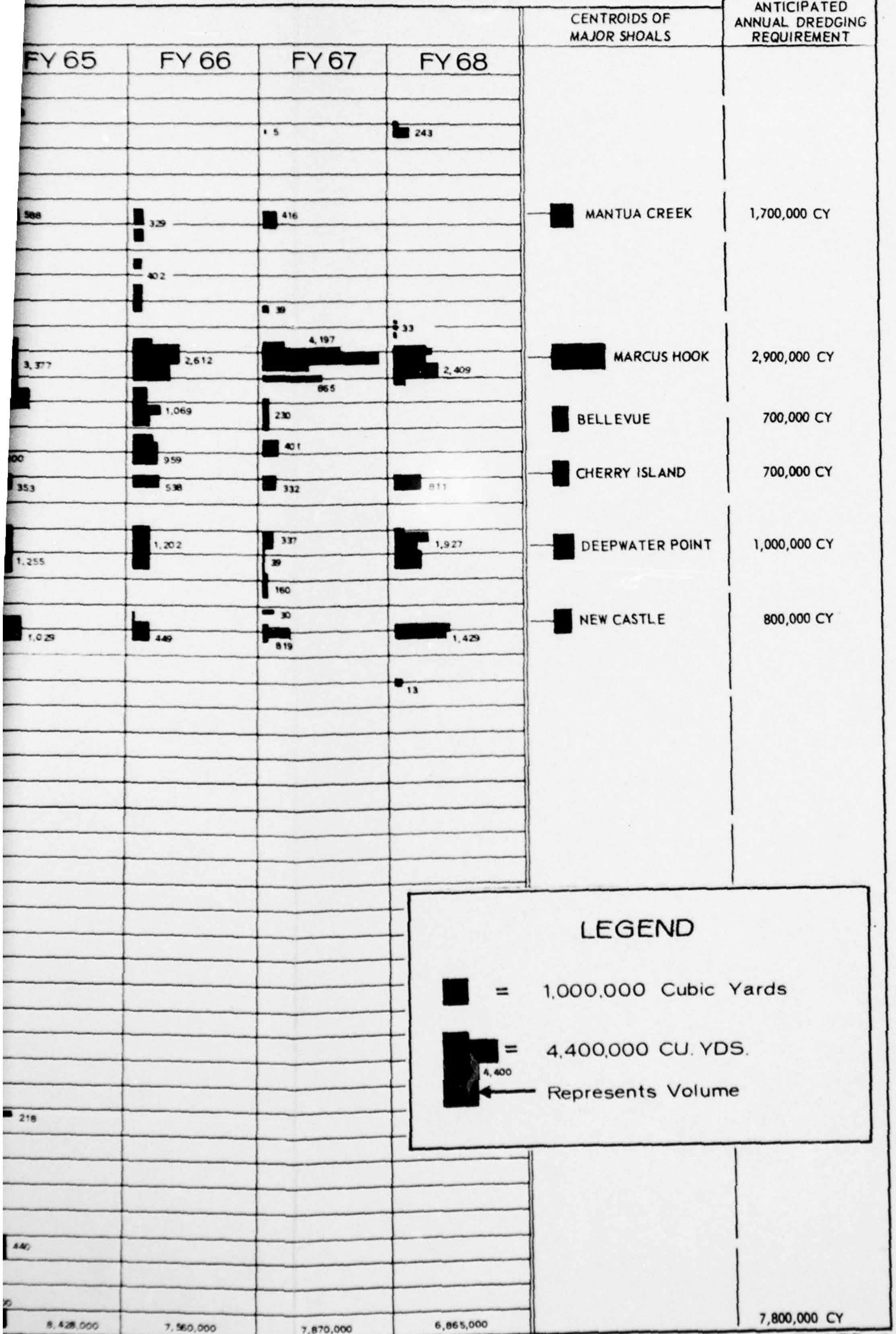

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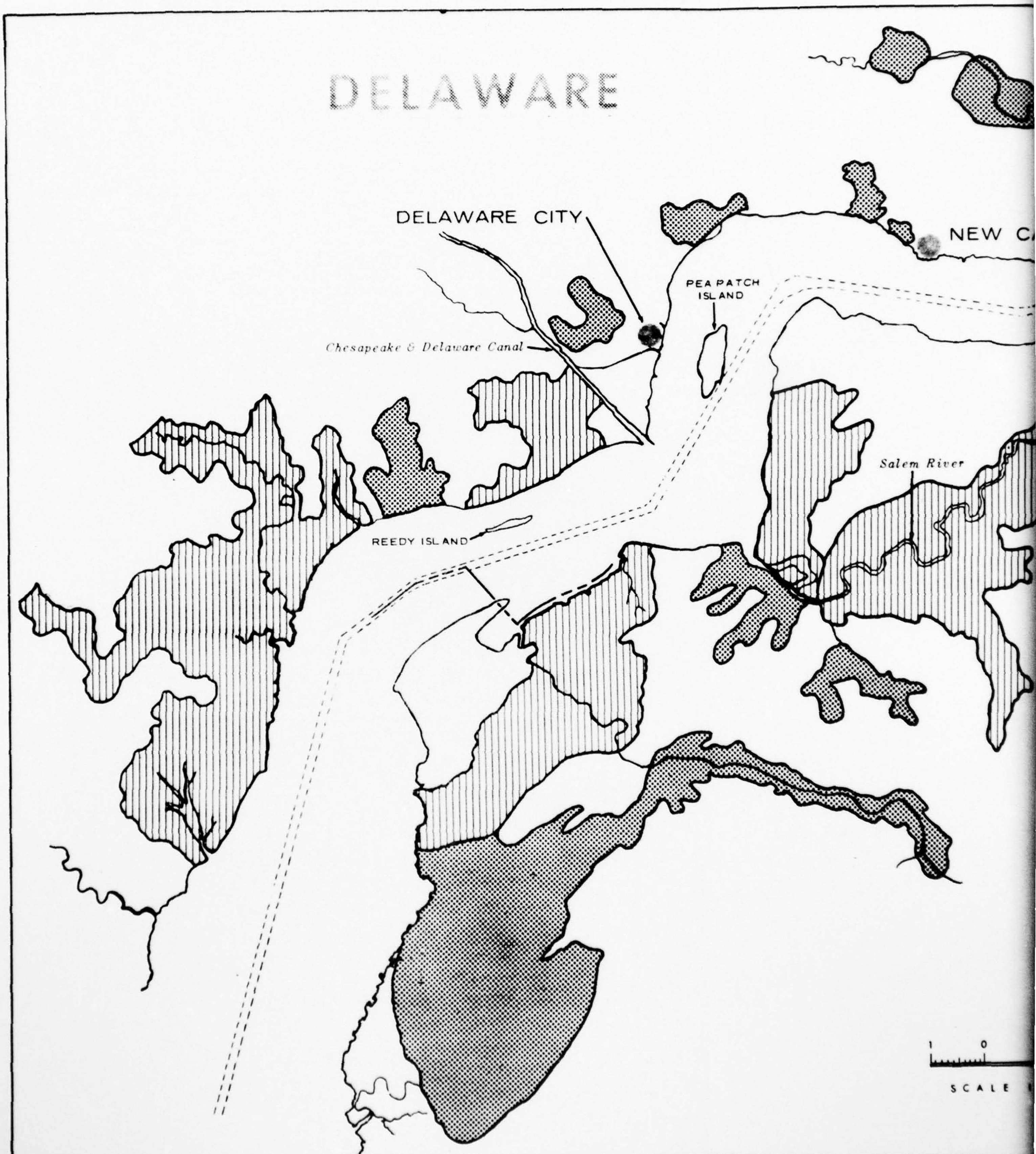
PLATE 2



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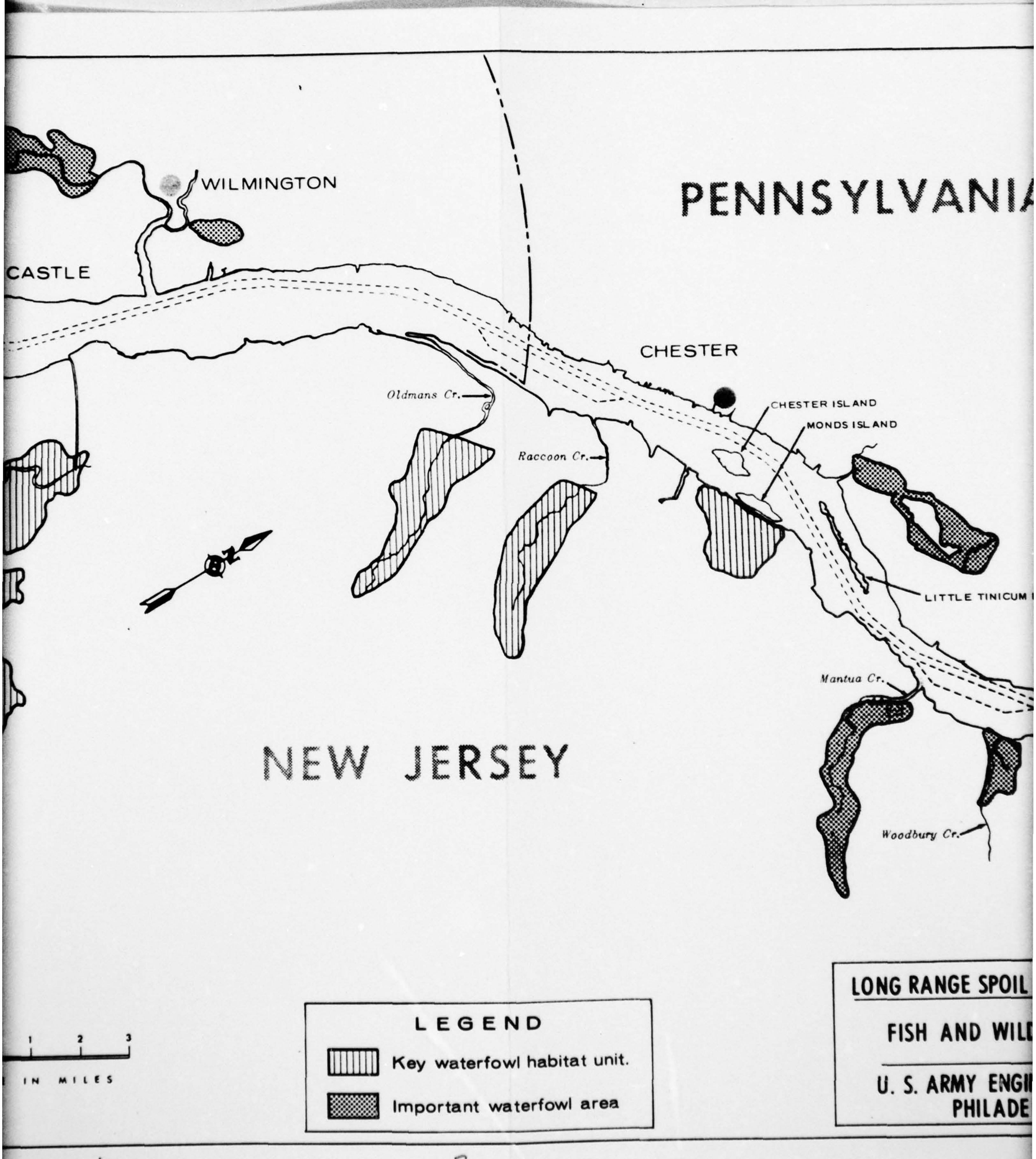

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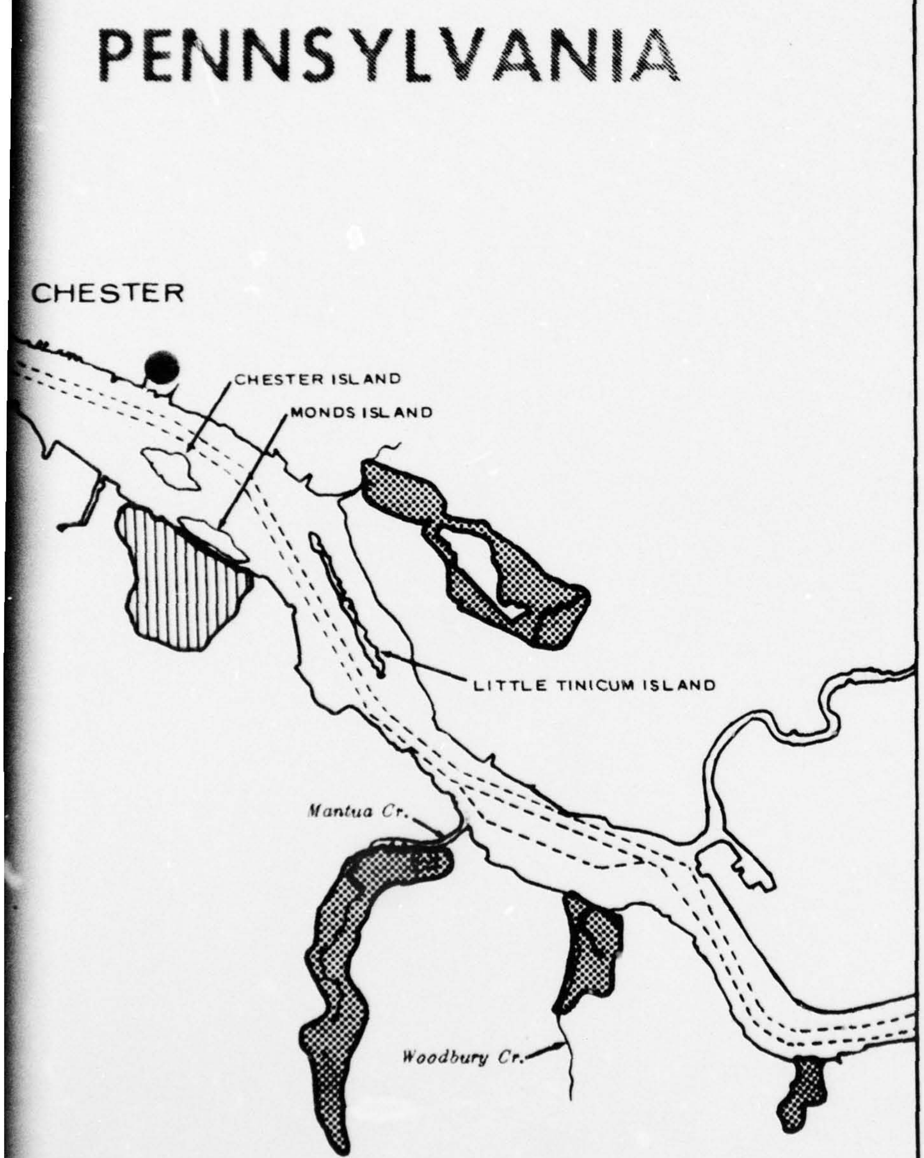

LONG RANGE SPOIL DISPOSAL STUDY

FISH AND WILDLIFE AREAS

U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

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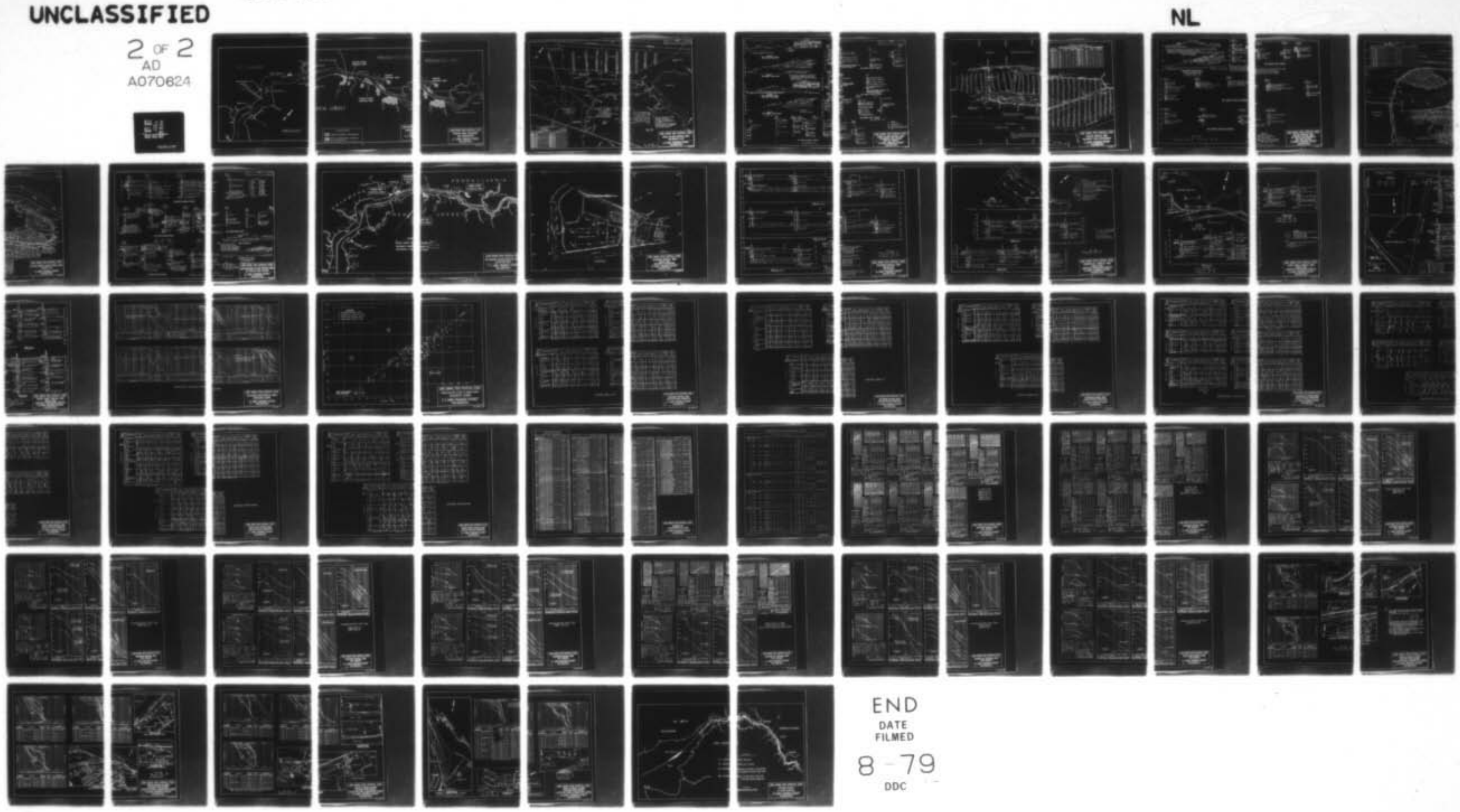

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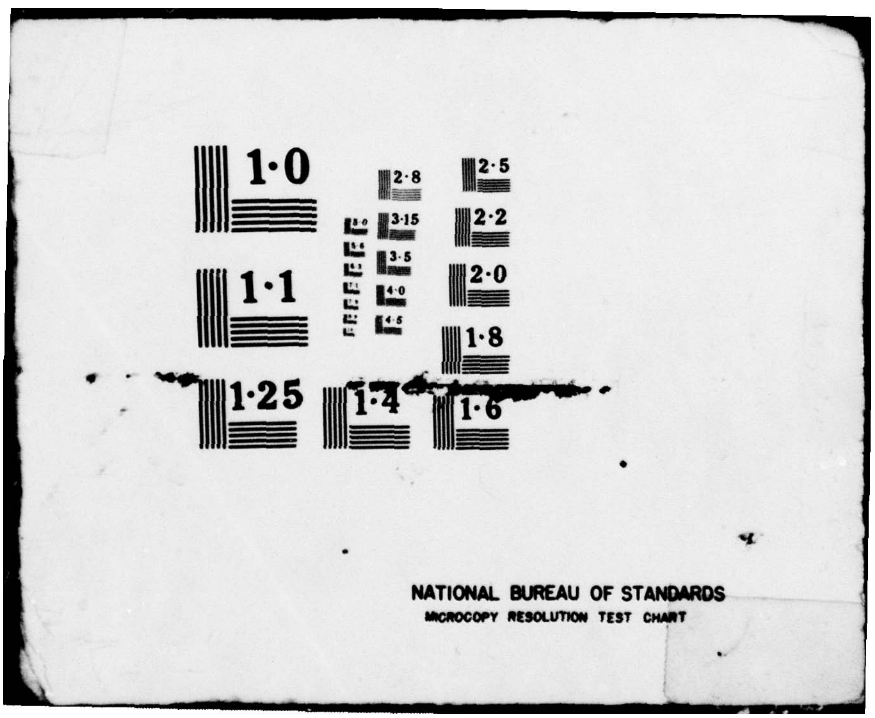
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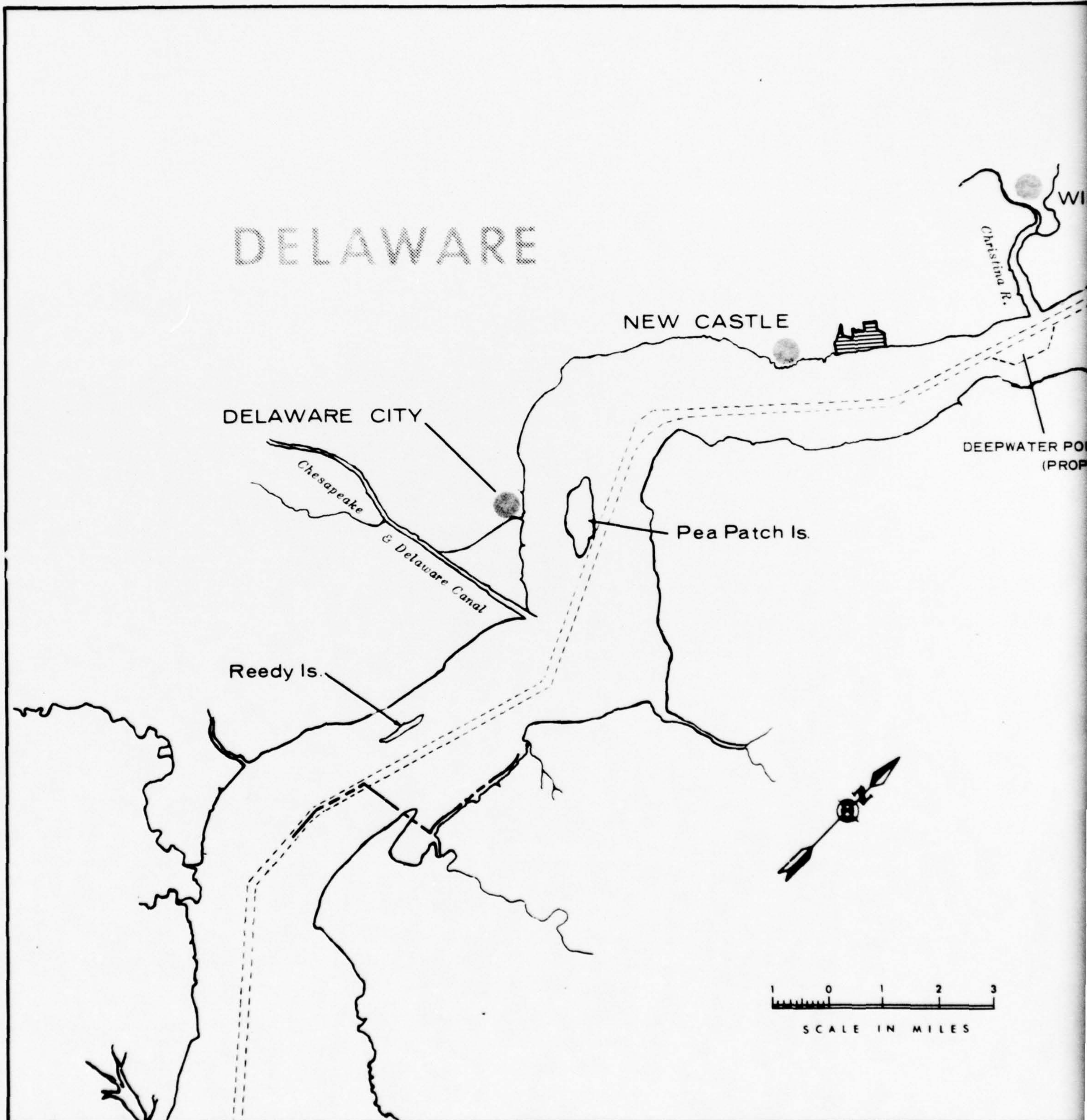
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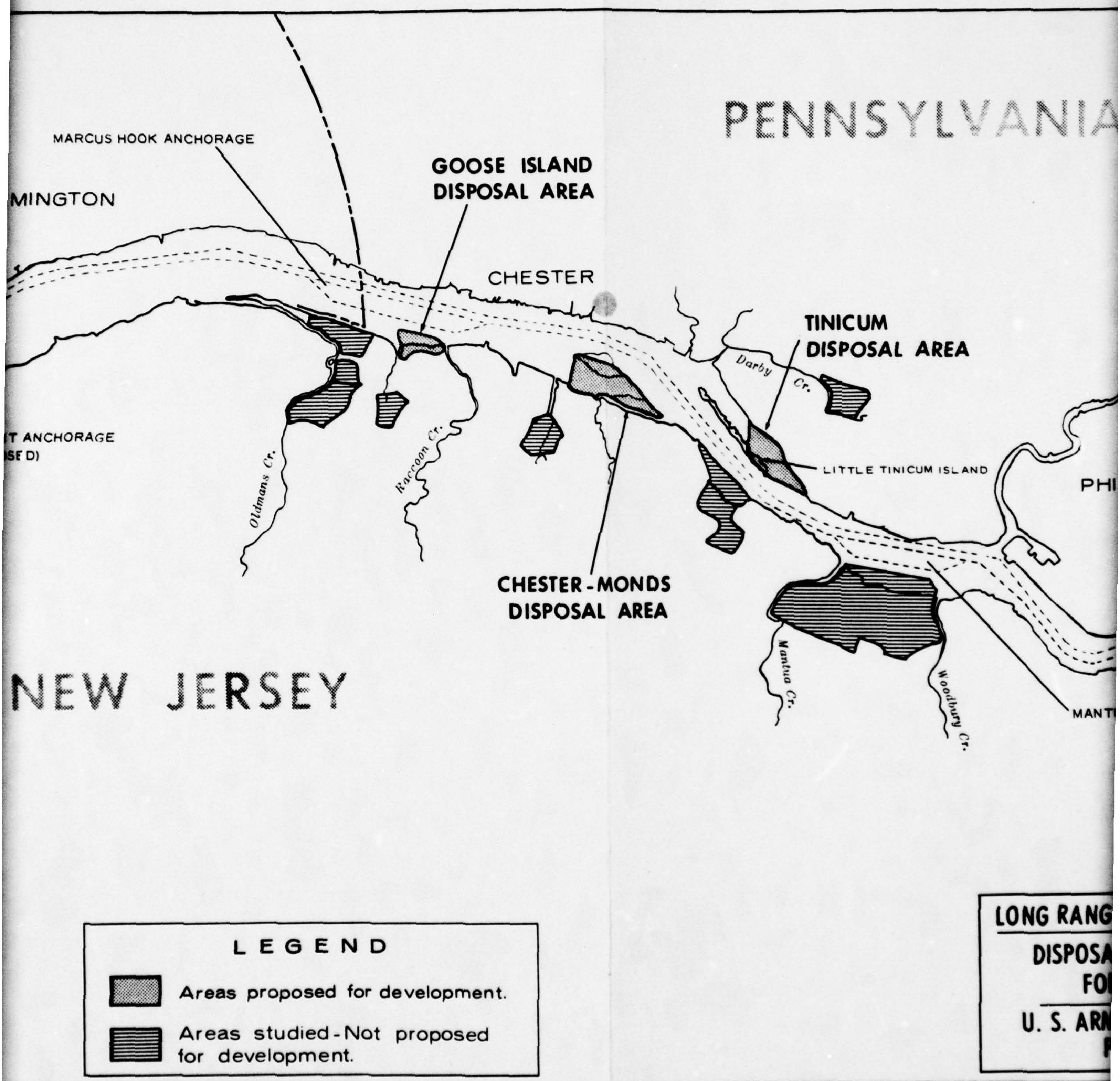
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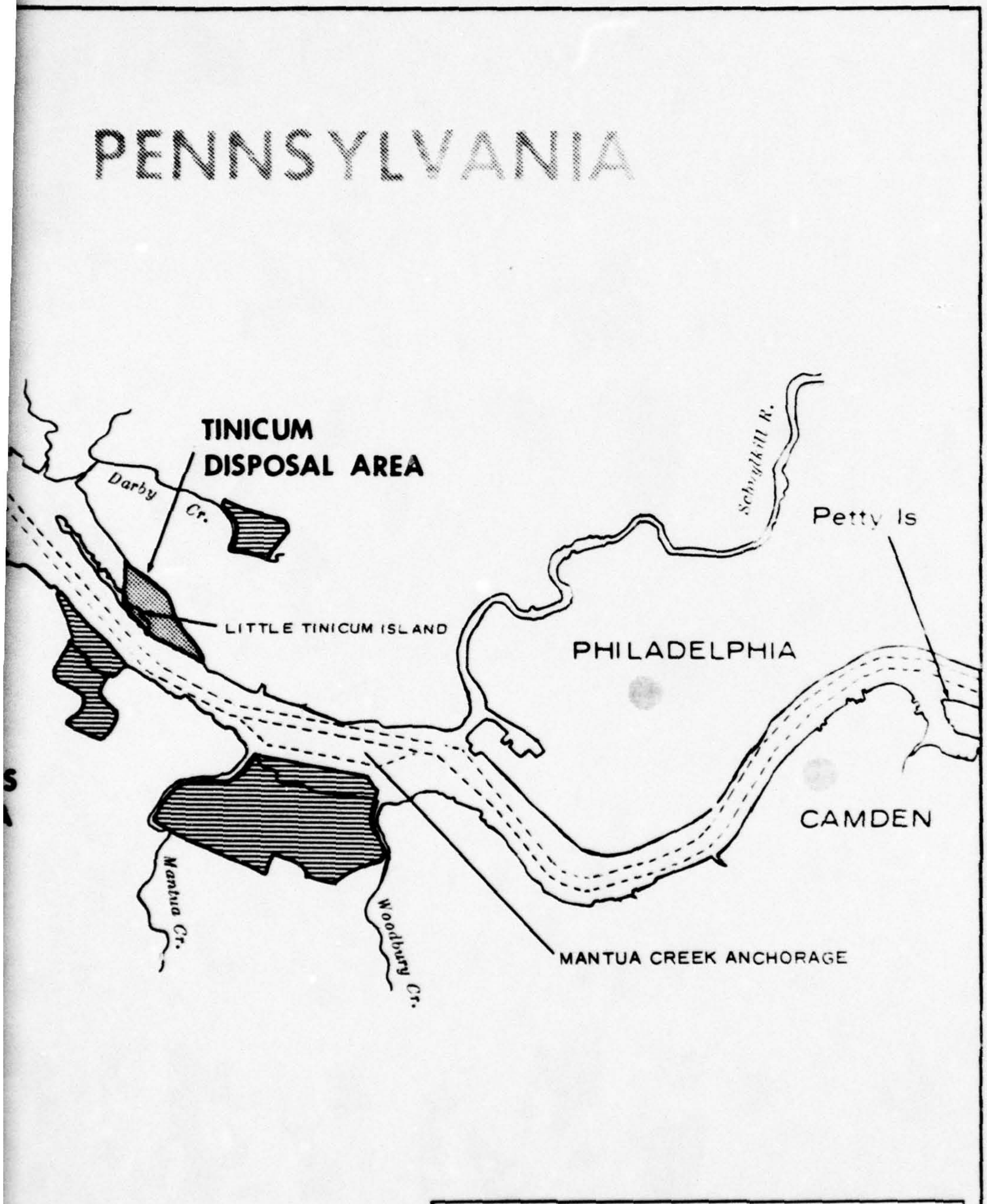
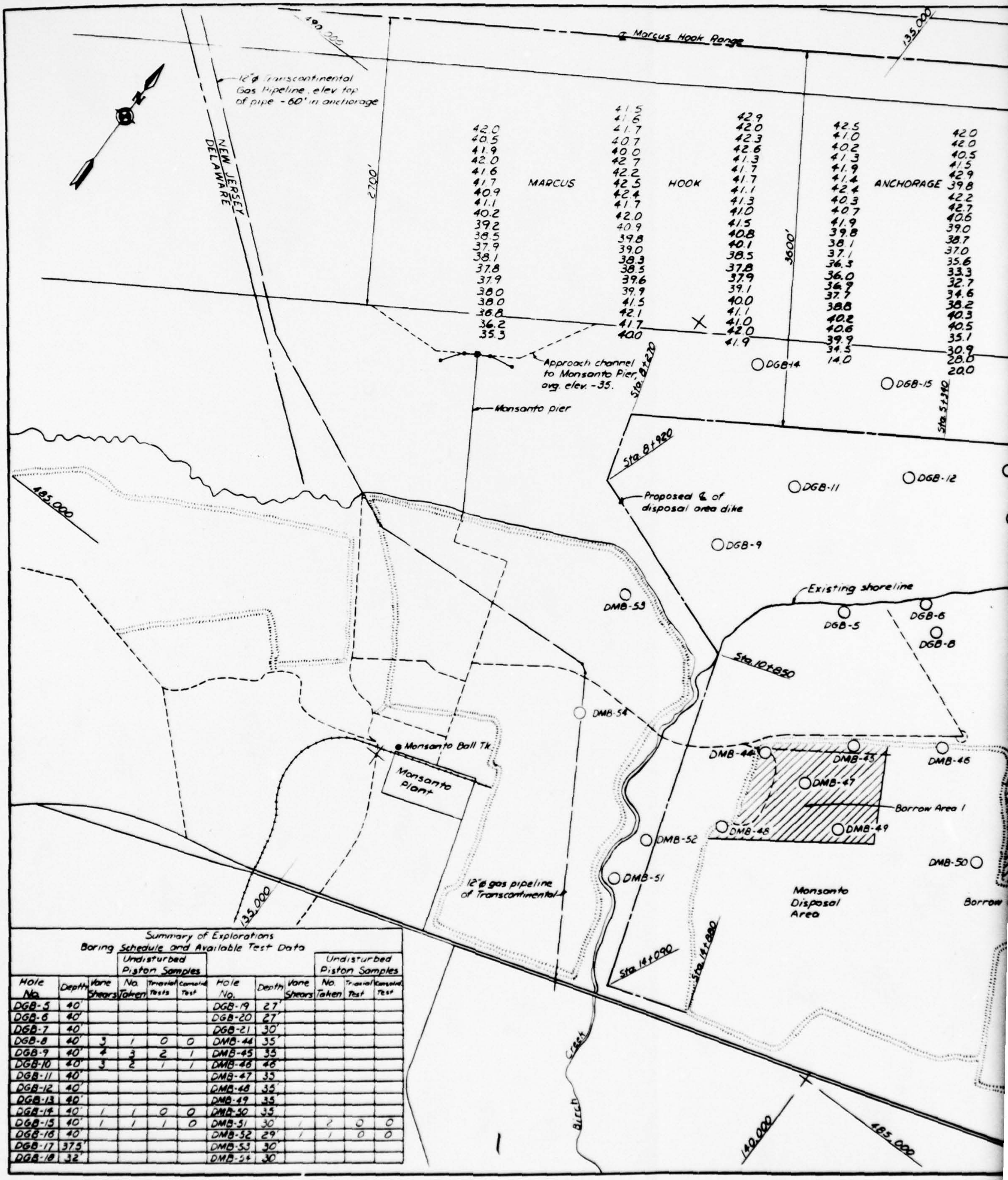


LONG RANGE SPOIL DISPOSAL STUDY

DISPOSAL AREAS CONSIDERED FOR DEVELOPMENT

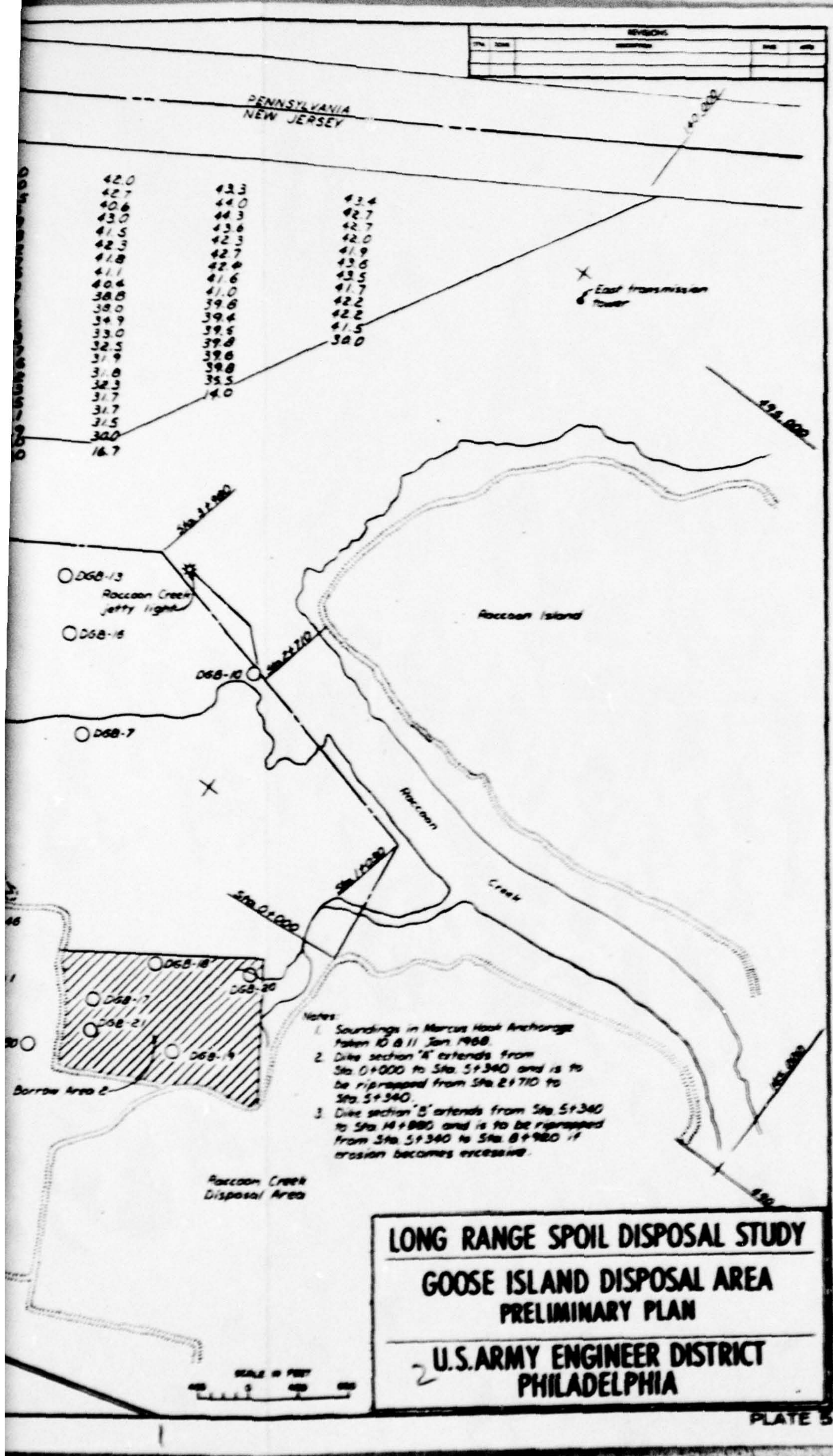
U. S. ARMY ENGINEER DISTRICT PHILADELPHIA

PLATE 4



Summary of Explorations
Boring Schedule and Available Test Data

Hole No.	Depth	Vane Shears	Undisturbed Piston Samples: No. Taken	Undisturbed Piston Samples: Triaxial Tests	Undisturbed Piston Samples: Consolid. Test	Hole No.	Depth	Vane Shears	Undisturbed Piston Samples: No. Taken	Undisturbed Piston Samples: Triaxial Test	Undisturbed Piston Samples: Consolid. Test
DGB-5	40'					DGB-19	27'				
DGB-6	40'					DGB-20	27'				
DGB-7	40'					DGB-21	30'				
DGB-8	40'	3	1	0	0	DMB-44	35'				
DGB-9	40'	4	3	2	1	DMB-45	35'				
DGB-10	40'	3	2	1	1	DMB-46	46'				
DGB-11	40'					DMB-47	35'				
DGB-12	40'					DMB-48	35'				
DGB-13	40'					DMB-49	35'				
DGB-14	40'	1	1	0	0	DMB-50	35'				
DGB-15	40'	1	1	1	0	DMB-51	30'	1	2	0	0
DGB-16	40'					DMB-52	29'	1	1	0	0
DGB-17	37.5'					DMB-53	30'				
DGB-18	32'					DMB-54	30'				

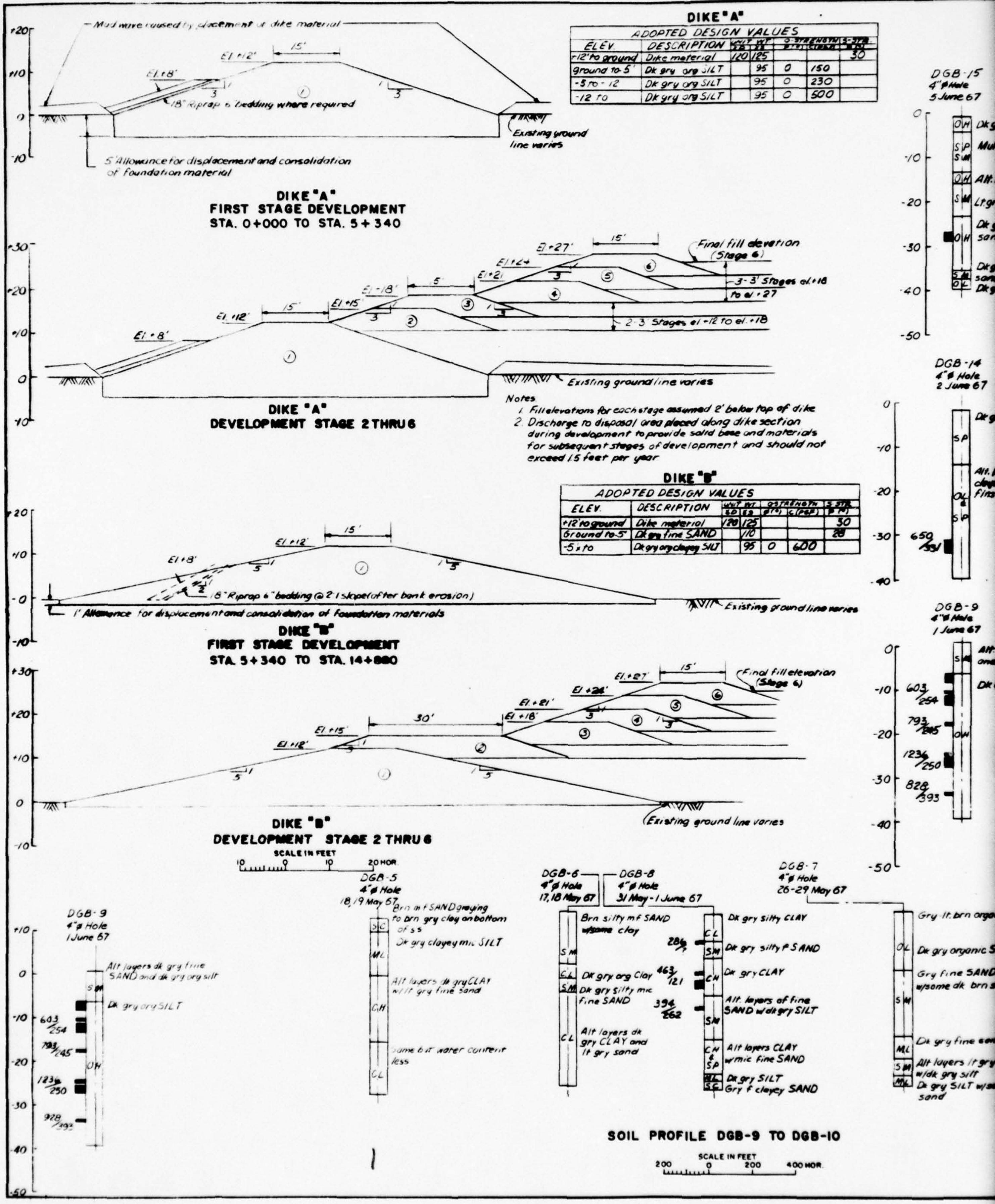


LONG RANGE SPOIL DISPOSAL STUDY

GOOSE ISLAND DISPOSAL AREA
PRELIMINARY PLAN

U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 5



DIKE "A"

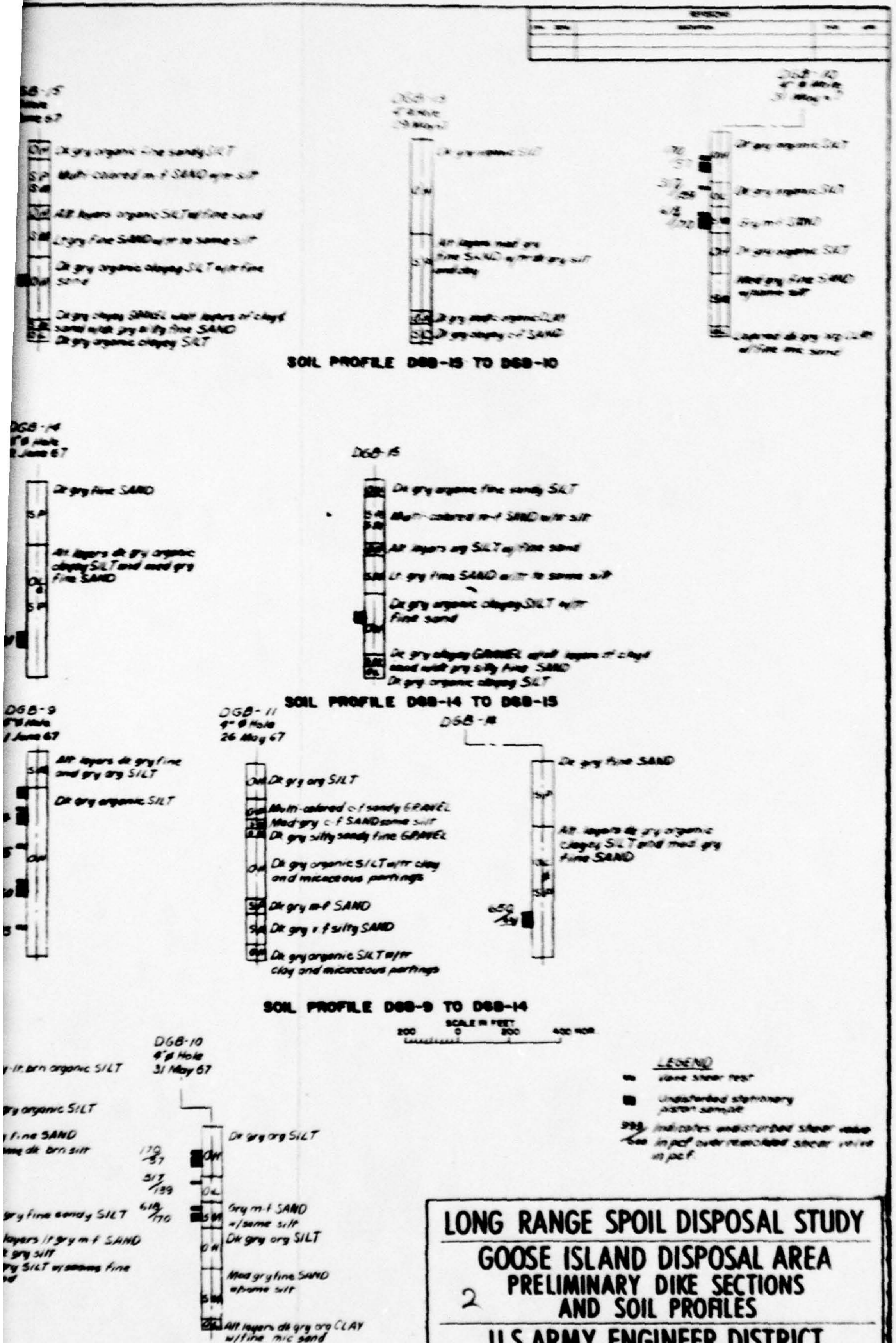
ADOPTED DESIGN VALUES

ELEV.	DESCRIPTION	UNIT WT SD	UNIT WT SS	Q-STRENGTH φ (°)	Q-STRENGTH c (PSF)	S-STR φ (°)
+12' to ground	Dike material	120	125			30
ground to -5'	Dk gry org SILT		95	0	150	
-5 to -12	Dk gry org SILT		95	0	230	
-12 to	Dk gry org SILT		95	0	500	

DIKE "B"

ADOPTED DESIGN VALUES

ELEV.	DESCRIPTION	UNIT WT SD	UNIT WT SS	Q-STRENGTH φ (°)	Q-STRENGTH c (PSF)	S-STR φ (°)
+12 to ground	Dike material	120	125			30
Ground to -5'	Dk gry fine SAND		110			28
-5 to	Dk gry org clayey SILT		95	0	600	



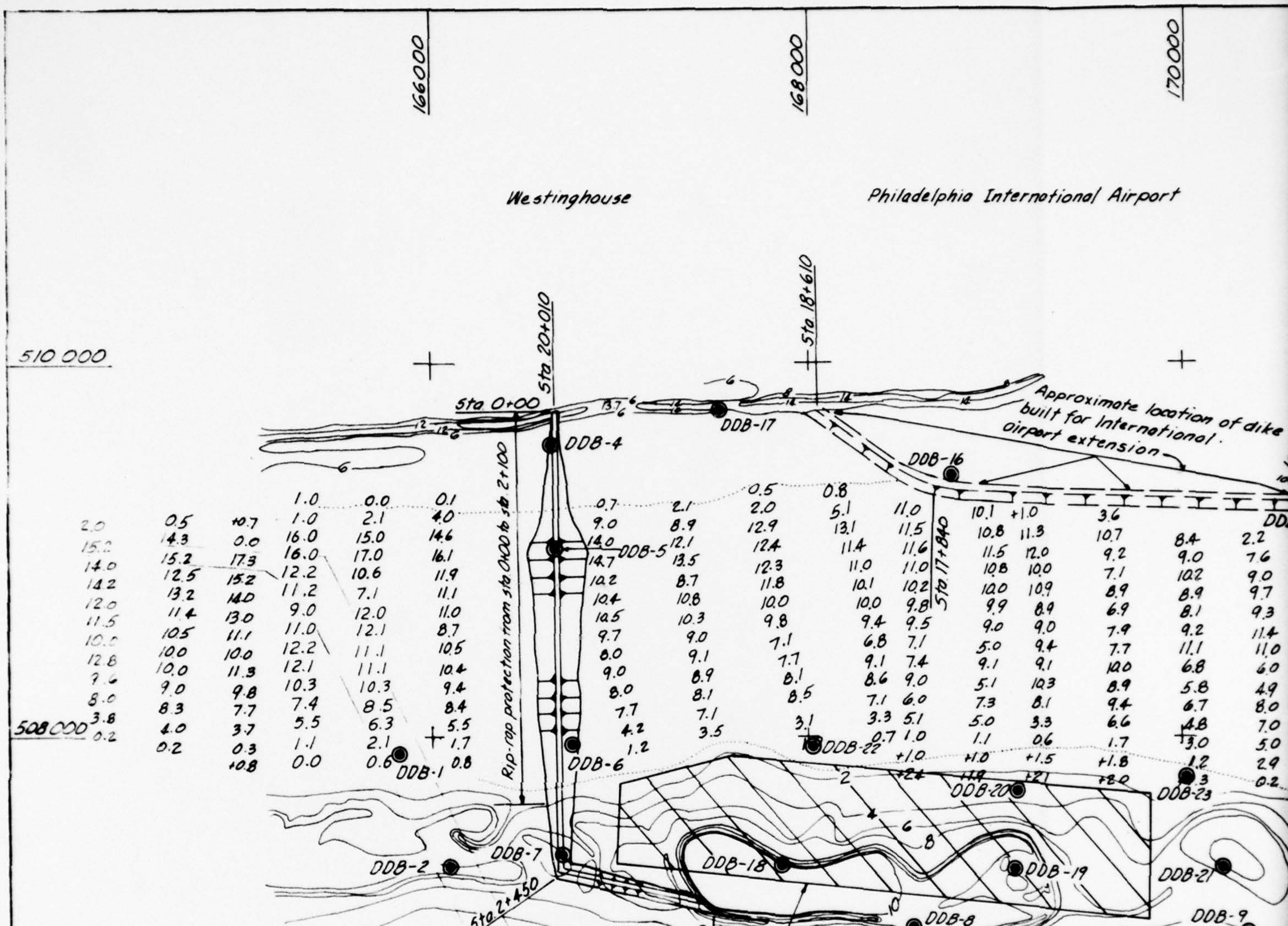
LONG RANGE SPOIL DISPOSAL STUDY

GOOSE ISLAND DISPOSAL AREA
PRELIMINARY DIKE SECTIONS
AND SOIL PROFILES

2

U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

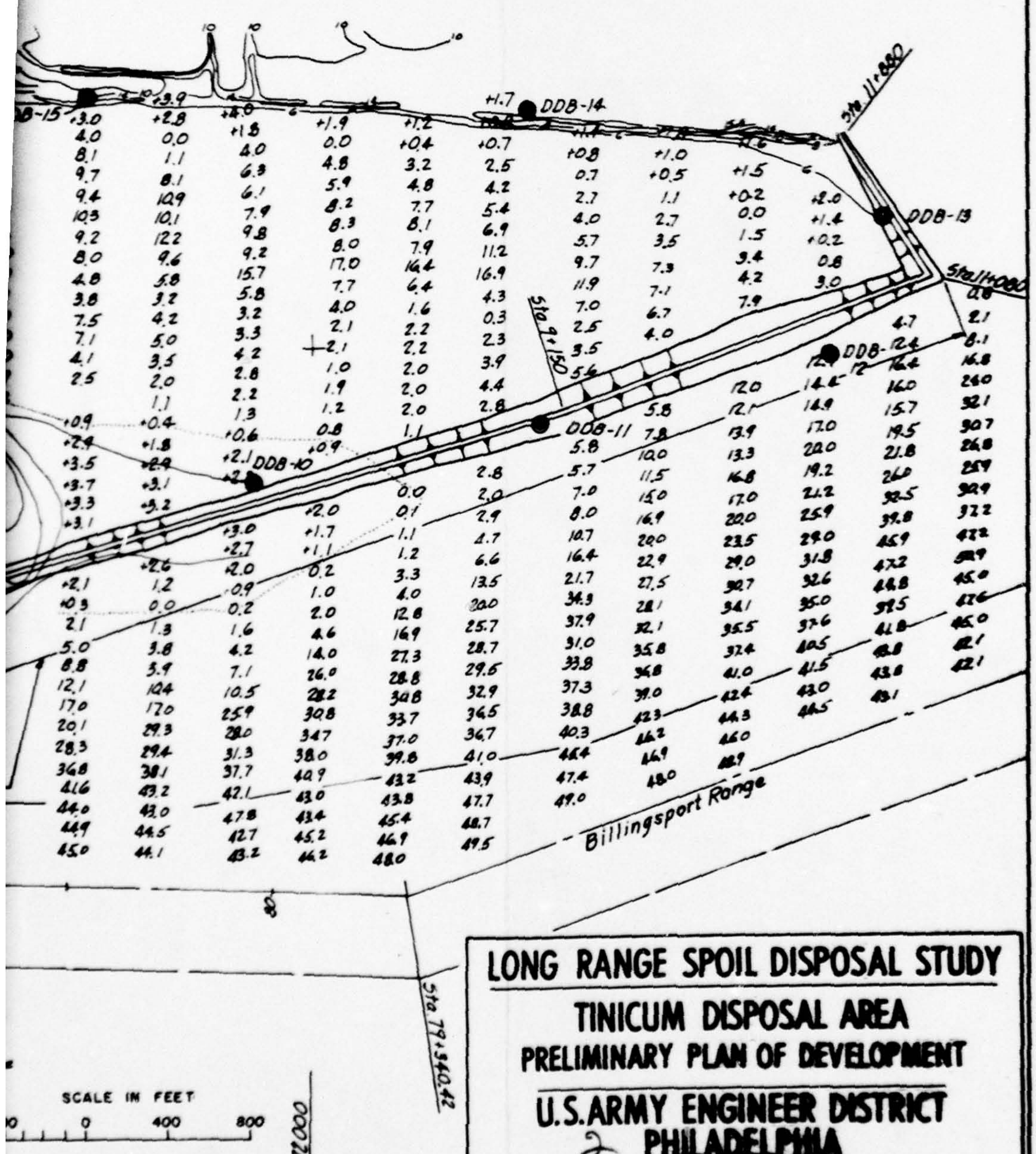
PLATE 6


166000
168000
170000
Westinghouse
Philadelphia International Airport
510 000
508 000
506000
Sta 0+00
Sta 20+010
Sta 18+610
Sta 17+840
Approximate location of dike built for International airport extension
Rip-rap protection from sta 0+00 to sta 2+100
DDB-1
DDB-2
DDB-3
DDB-4
DDB-5
DDB-6
DDB-7
DDB-8
DDB-9
DDB-16
DDB-17
DDB-18
DDB-19
DDB-20
DDB-21
DDB-22
DDB-23
Sta 2+450
Sta 3+230
Sta 4+690
Sta 6+070
Proposed location of new channel
Interior limit (Toe of slope) of proposed borrow area
Rip-rap protection from sta. 6+070 to sta. 11+080
Tinicum Range
DELAWARE RIVER
ebb
Note:
Existing dike from sta 3+230 to sta 4+690 and sta 11+880 to sta 20+010 to remain in place and be reshaped to top el. +15 for stage 1 diking
400

SUMMARY OF EXPLORATIONS

BORING SCHEDULE & SPECIAL TESTING & SAMPLING

HOLE DESIGNATION	DEPTH	VANE SHEAR TESTS	UNDISTURBED SAMPLES	HOLE DESIGNATION	DEPTH	VANE SHEAR TESTS	UNDISTURBED SAMPLES
DDB-1	15	—	—	DDB-13	40	—	—
DDB-2	20	—	—	DDB-14	39	—	1
DDB-3	16	—	—	DDB-15	42	—	—
DDB-4	40	3	1	DDB-16	40	1	—
DDB-5	40	2	—	DDB-17	40	1	—
DDB-6	40	2	—	DDB-18	20	—	—
DDB-7	70	—	1	DDB-19	22	—	—
DDB-8	40	—	—	DDB-20	15	—	—
DDB-9	40	—	—	DDB-21	22	—	—
DDB-10	40	—	—	DDB-22	40	—	—
DDB-11	40	2	1	DDB-23	32	—	—
DDB-12	40	2	1				



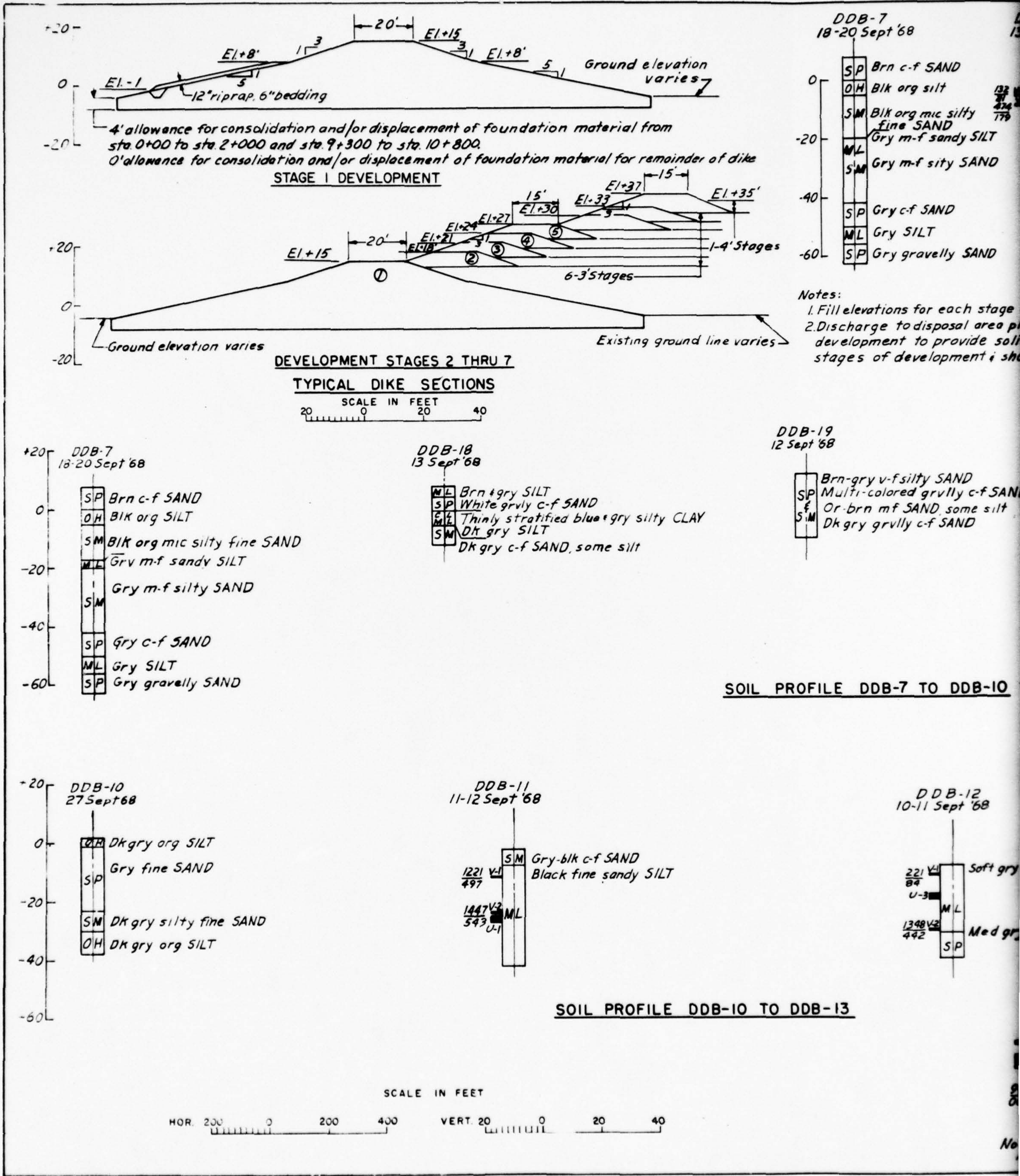
LONG RANGE SPOIL DISPOSAL STUDY

TINICUM DISPOSAL AREA

PRELIMINARY PLAN OF DEVELOPMENT

U.S. ARMY ENGINEER DISTRICT PHILADELPHIA

PLATE 7



El.+8'
El.+15
El.+8'
20'
Ground elevation varies
El.-1
12" riprap, 6" bedding
4' allowance for consolidation and/or displacement of foundation material from sta. 0+00 to sta. 2+000 and sta. 9+300 to sta. 10+800.
0' allowance for consolidation and/or displacement of foundation material for remainder of dike
STAGE I DEVELOPMENT
El.+15
20'
El.+18'
El.+21
El.+24
El.+27
El.+30
El.-33
El.+37
El.+35'
15'
1-4' Stages
6-3' Stages
Ground elevation varies
Existing ground line varies
DEVELOPMENT STAGES 2 THRU 7
TYPICAL DIKE SECTIONS
SCALE IN FEET
DDB-7
18-20 Sept '68
SP Brn c-f SAND
OH Blk org silt
SM Blk org mic silty fine SAND
ML Gry m-f sandy SILT
SM Gry m-f sity SAND
SP Gry c-f SAND
ML Gry SILT
SP Gry gravelly SAND
Notes:
1. Fill elevations for each stage
2. Discharge to disposal area p
development to provide soi
stages of development & sh
DDB-7
18-20 Sept '68
SP Brn c-f SAND
OH Blk org SILT
SM Blk org mic silty fine SAND
ML Grv m-f sandv SILT
SM Gry m-f silty SAND
SP Gry c-f SAND
ML Gry SILT
SP Gry gravelly SAND
DDB-18
13 Sept '68
ML Brn & gry SILT
SP White grvly c-f SAND
CL ML Thinly stratified blue & gry silty CLAY
SM Dk gry SILT
Dk gry c-f SAND, some silt
DDB-19
12 Sept '68
SP & SM Brn-gry v-f silty SAND
Multi-colored grvlly c-f SAND
Or-brn mf SAND some silt
Dk gry grvlly c-f SAND
SOIL PROFILE DDB-7 TO DDB-10
DDB-10
27 Sept 68
OH Dk gry org SILT
SP Gry fine SAND
SM Dk gry silty fine SAND
OH Dk gry org SILT
DDB-11
11-12 Sept '68
SM Gry-blk c-f SAND
ML Black fine sandy SILT
1221/497 V-1
1447/543 V-2 U-1
DDB-12
10-11 Sept '68
221/84 V-1
U-3
1348/442 V-2
ML Soft gry
SP Med gr
SOIL PROFILE DDB-10 TO DDB-13
SCALE IN FEET
HOR. 200 0 200 400
VERT. 20 0 20 40

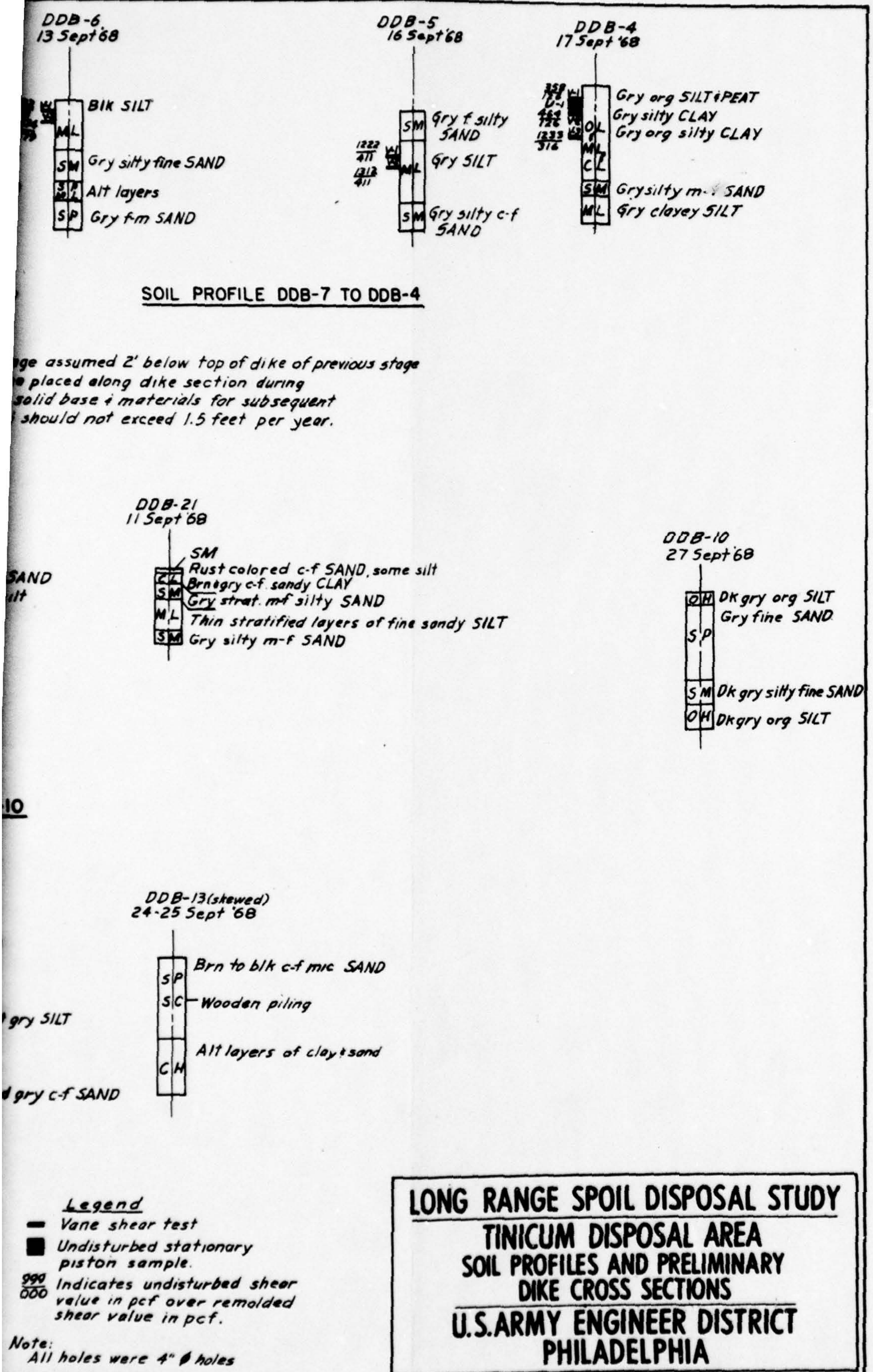
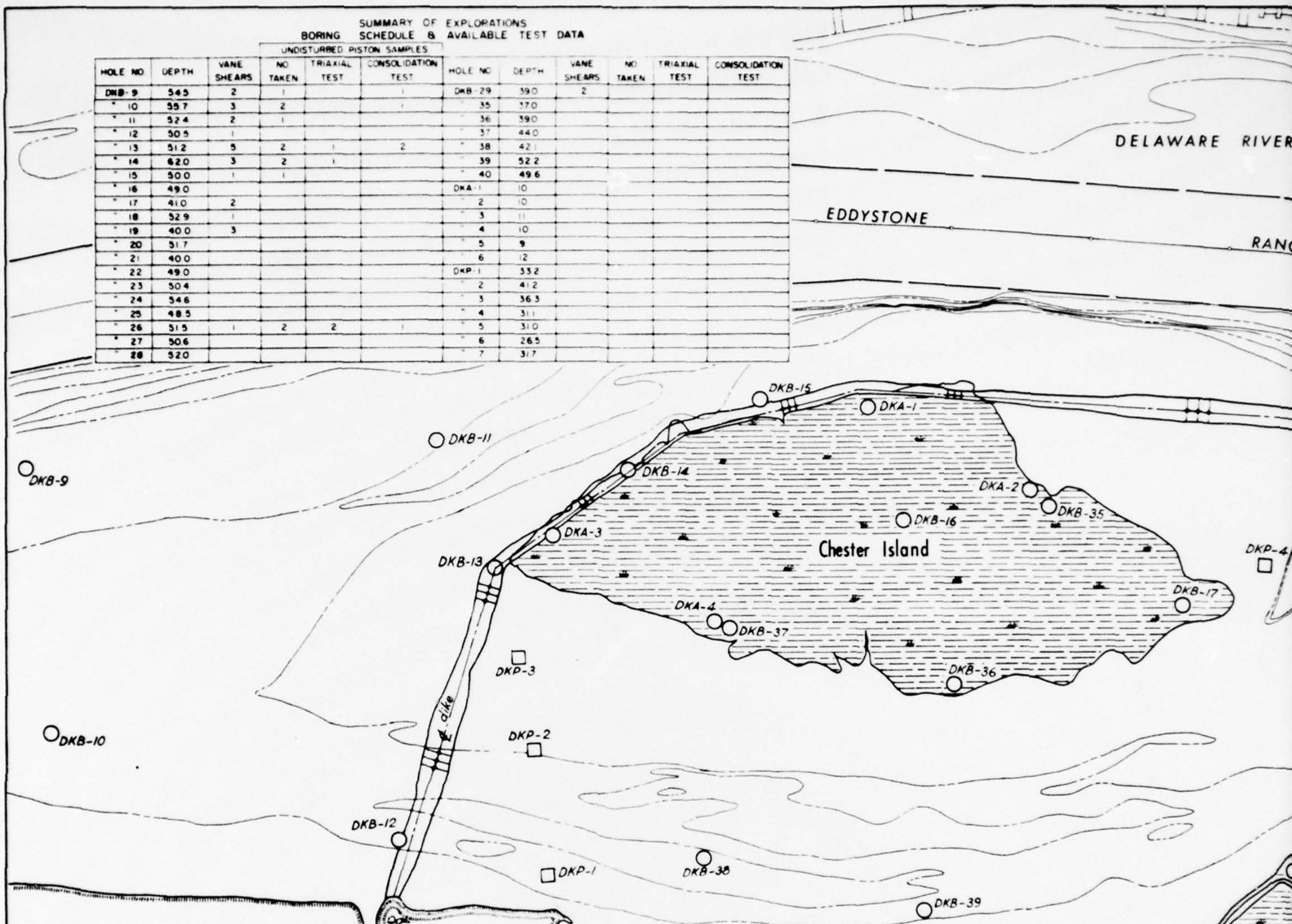
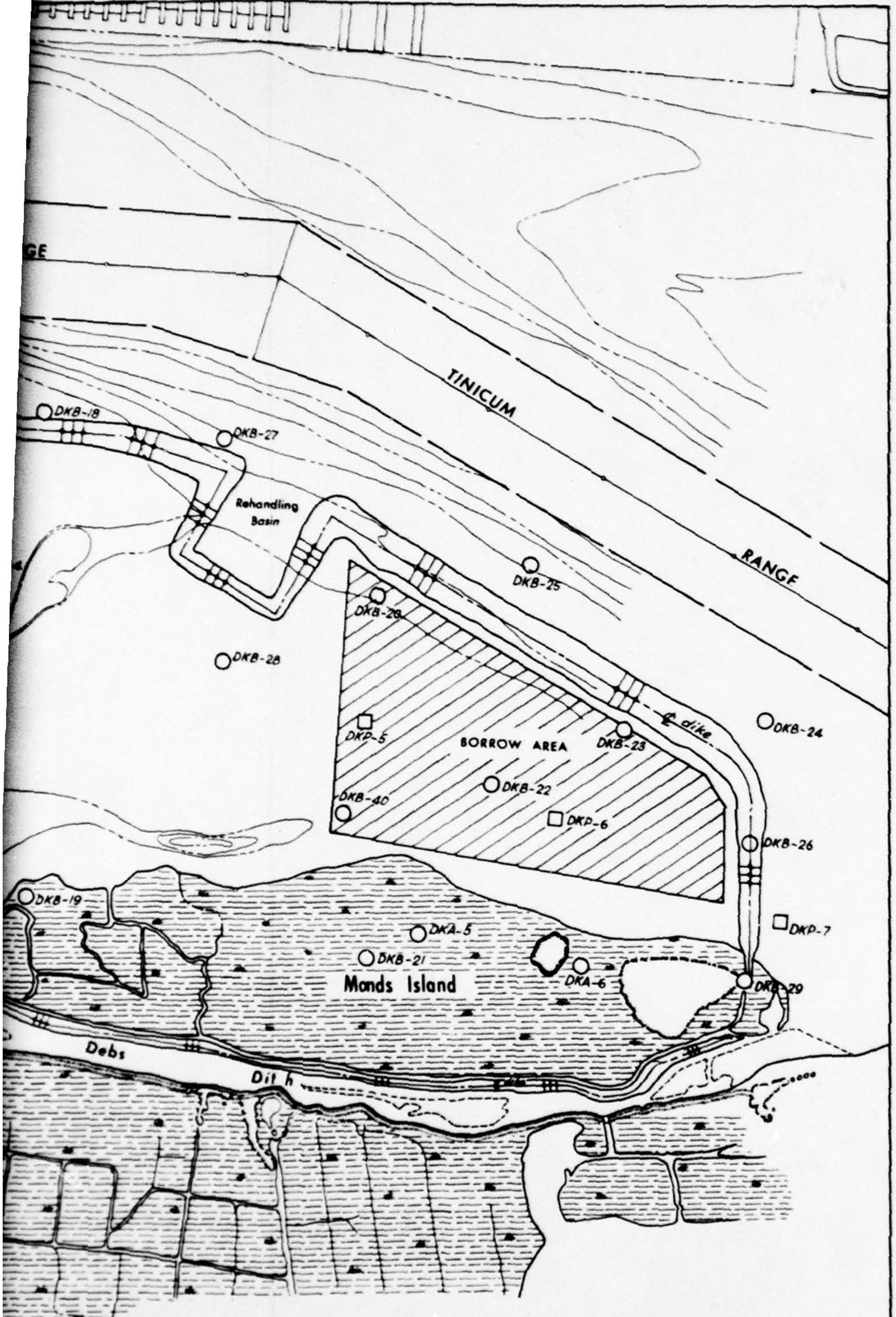

DDB-6
13 Sept 68
Blk SILT
ML
SM Gry silty fine SAND
Alt layers
SP Gry f-m SAND
DDB-5
16 Sept 68
SM Gry f silty SAND
Gry SILT
ML
SM Gry silty c-f SAND
DDB-4
17 Sept '68
Gry org SILT & PEAT
Gry silty CLAY
Gry org silty CLAY
OL
ML
CL
SM Gry silty m-f SAND
ML Gry clayey SILT
SOIL PROFILE DDB-7 TO DDB-4
ge assumed 2' below top of dike of previous stage
placed along dike section during
solid base & materials for subsequent
should not exceed 1.5 feet per year.
DDB-21
11 Sept 68
SM
Rust colored c-f SAND, some silt
CL Brn & gry c-f sandy CLAY
SM Gry strat. m-f silty SAND
ML Thin stratified layers of fine sandy SILT
SM Gry silty m-f SAND
SAND
ilt
DDB-10
27 Sept 68
OH Dk gry org SILT
Gry fine SAND
SP
SM Dk gry silty fine SAND
OH Dk gry org SILT
10
DDB-13 (skewed)
24-25 Sept '68
Brn to blk c-f mic SAND
SP
SC Wooden piling
Alt layers of clay & sand
CH
gry SILT
gry c-f SAND
Legend
Vane shear test
Undisturbed stationary piston sample.
999/000 Indicates undisturbed shear value in pcf over remolded shear value in pcf.
Note:
All holes were 4" Ø holes
LONG RANGE SPOIL DISPOSAL STUDY
TINICUM DISPOSAL AREA
SOIL PROFILES AND PRELIMINARY
DIKE CROSS SECTIONS
U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 8

SUMMARY OF EXPLORATIONS
BORING SCHEDULE & AVAILABLE TEST DATA

			UNDISTURBED PISTON SAMPLES								
HOLE NO	DEPTH	VANE SHEARS	NO TAKEN	TRIAXIAL TEST	CONSOLIDATION TEST	HOLE NO	DEPTH	VANE SHEARS	NO TAKEN	TRIAXIAL TEST	CONSOLIDATION TEST
DKB-9	54.5	2	1		1	DKB-29	39.0	2			
" 10	55.7	3	2		1	" 35	37.0				
" 11	52.4	2	1			" 36	39.0				
" 12	50.5	1				" 37	44.0				
" 13	51.2	5	2	1	2	" 38	42.1				
" 14	62.0	3	2	1		" 39	52.2				
" 15	50.0	1	1			" 40	49.6				
" 16	49.0					DKA-1	10				
" 17	41.0	2				" 2	10				
" 18	52.9	1				" 3	11				
" 19	40.0	3				" 4	10				
" 20	51.7					" 5	9				
" 21	40.0					" 6	12				
" 22	49.0					DKP-1	33.2				
" 23	50.4					" 2	41.2				
" 24	54.6					" 3	36.3				
" 25	48.5					" 4	31.1				
" 26	51.5	1	2	2	1	" 5	31.0				
" 27	50.6					" 6	26.5				
" 28	52.0					" 7	31.7				



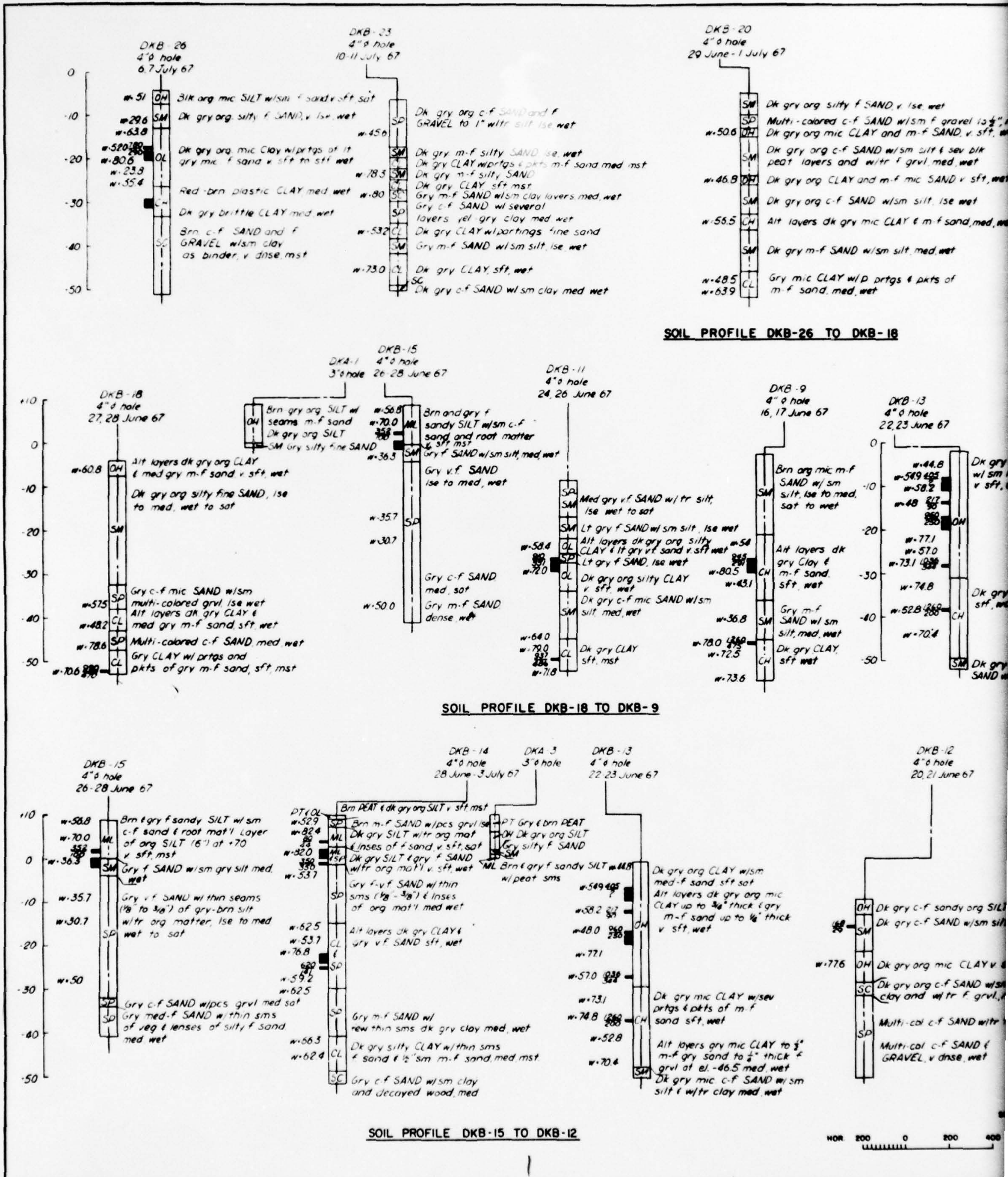


LONG RANGE SPOIL DISPOSAL STUDY

CHESTER-MONDS ISLAND DISPOSAL AREA
GENERAL PLAN

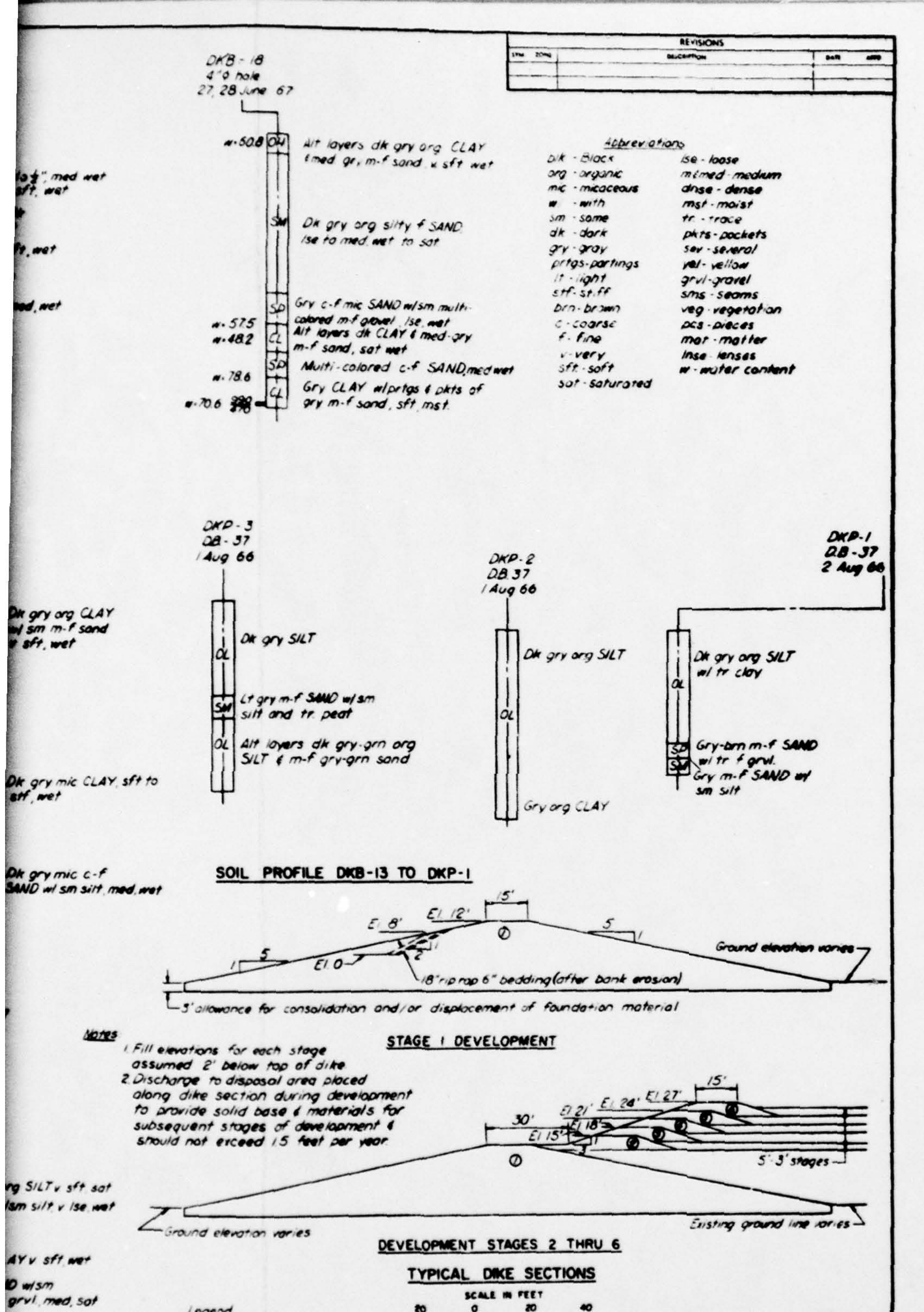
U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

1 2



DKB-26
4" ϕ hole
6,7 July 67
Blk org mic SILT w/sm f sand v sft sat
Dk gry org silty f SAND v lse wet
Dk gry org mic Clay w/prtgs of lt gry mic f sand v sft to sft wet
Red-brn plastic CLAY med wet
Dk gry brittle CLAY med wet
Brn c-f SAND and f GRAVEL w/sm clay as binder, v dnse, mst
DKB-23
4" ϕ hole
10-11 July 67
Dk gry org c-f SAND and f GRAVEL to 1" w/tr silt lse wet
Dk gry m-f silty SAND lse wet
Dk gry CLAY w/prtgs & pkts m-f sand med mst
Dk gry m-f silty SAND
Dk gry CLAY sft mst
Gry m-f SAND w/sm clay layers med wet
Gry c-f SAND w/ several layers yel-gry clay med wet
Dk gry CLAY w/partings fine sand
Gry m-f SAND w/sm silt lse wet
Dk gry CLAY, sft, wet
Dk gry c-f SAND w/ sm clay med wet
DKB-20
4" ϕ hole
29 June - 1 July 67
Dk gry org silty f SAND v lse wet
Multi-colored c-f SAND w/sm f gravel
Dk gry org mic CLAY and m-f SAND v sft
Dk gry org c-f SAND w/sm silt & sev blk peat layers and w/tr f grvl, med, wet
Dk gry org CLAY and m-f mic SAND v sft, wet
Dk gry org c-f SAND w/sm silt lse wet
Alt layers dk gry mic CLAY & m-f sand, med, wet
Dk gry m-f SAND w/sm silt med wet
Gry mic CLAY w/p prtgs & pkts of m-f sand, med, wet
SOIL PROFILE DKB-26 TO DKB-18
DKB-18
4" ϕ hole
27, 28 June 67
Alt layers dk gry org CLAY & med gry m-f sand v sft, wet
Dk gry org silty fine SAND, lse to med, wet to sat
Gry c-f mic SAND w/sm multi-colored grvl, lse wet
Alt layers dk gry CLAY & med gry m-f sand, sft, wet
Multi-colored c-f SAND med wet
Gry CLAY w/ prtgs and pkts of gry m-f sand, sft, mst
DKA-1
3" ϕ hole
Brn gry org SILT w/ seams m-f sand
Dk gry org SILT
SM Gry silty fine SAND
DKB-15
4" ϕ hole
26-28 June 67
Brn and gry f sandy SILT w/sm c-f sand and root matter v sft mst
Gry f SAND w/sm silt, med, wet
Gry v.f. SAND lse to med, wet
Gry c-f SAND med, sat
Gry m-f SAND dense, wet
DKB-11
4" ϕ hole
24, 26 June 67
Med gry v.f. SAND w/ tr silt, lse wet to sat
Lt gry f SAND w/ sm silt, lse wet
Alt layers dk gry org silty CLAY & lt gry v.f. sand v sft wet
Lt gry f SAND, lse wet
Dk gry org silty CLAY v sft, wet
Dk gry c-f mic SAND w/sm silt, med, wet
Dk gry CLAY sft, mst
DKB-9
4" ϕ hole
16, 17 June 67
Brn org mic m-f SAND w/ sm silt, lse to med, sat to wet
Alt layers dk gry Clay & m-f sand, sft, wet
Gry m-f SAND w/ sm silt, med, wet
Dk gry CLAY, sft wet
DKB-13
4" ϕ hole
22, 23 June 67
SOIL PROFILE DKB-18 TO DKB-9
DKB-15
4" ϕ hole
26-28 June 67
Brn & gry f sandy SILT w/ sm c-f sand & root mat'l Layer of org SILT (6") at +7.0 v sft, mst
Gry f SAND w/sm gry silt med, wet
Gry v f SAND w/ thin seams (1/8" to 3/8") of gry-brn silt w/tr org matter, lse to med wet to sat
Gry c-f SAND w/pcs grvl med sat
Gry med-f SAND w/ thin sms of veg & lenses of silty f sand med wet
DKB-14
4" ϕ hole
28 June - 3 July 67
Brn PEAT & dk gry org SILT v sft mst
Brn m-f SAND w/pcs grvl lse
Dk gry SILT w/tr org mat & lnses of f sand, v sft, sat
Dk gry SILT & gry f SAND w/tr org mat'l v. sft, wet
Gry f-v.f SAND w/ thin sms (1/8 - 3/8") & lnses of org mat'l med wet
Alt layers dk gry CLAY & gry v.f SAND sft, wet
Gry m-f SAND w/ few thin sms dk gry clay med, wet
Dk gry silty CLAY w/thin sms f sand & 1/2" sm m-f sand, med, mst
Gry c-f SAND w/sm clay and decayed wood, med
DKA-3
3" ϕ hole
PT Gry & brn PEAT
OH Dk gry org SILT
Gry silty f SAND
ML Brn & gry f sandy SILT w/peat sms
DKB-13
4" ϕ hole
22, 23 June 67
Dk gry org CLAY w/sm med-f sand sft sat
Alt layers dk gry org mic CLAY up to 3/4" thick & gry m-f sand up to 1/8" thick v sft, wet
Dk gry mic CLAY w/sev prtgs & pkts of m-f sand sft, wet
Alt layers gry mic CLAY to 1/2" m-f gry sand to 1/4" thick & grvl at el. -46.5 med, wet
Dk gry mic c-f SAND w/ sm silt & w/tr clay med, wet
DKB-12
4" ϕ hole
20, 21 June 67
Dk gry c-f sandy org SILT
Dk gry c-f SAND w/sm silt
Dk gry org mic CLAY
Dk gry org c-f SAND w/sm clay and w/tr f grvl
Multi-col c-f SAND w/tr
Multi-col c-f SAND & GRAVEL, v dnse, wet
SOIL PROFILE DKB-15 TO DKB-12
HOR. 200 0 200 400

1



LONG RANGE SPOIL DISPOSAL STUDY

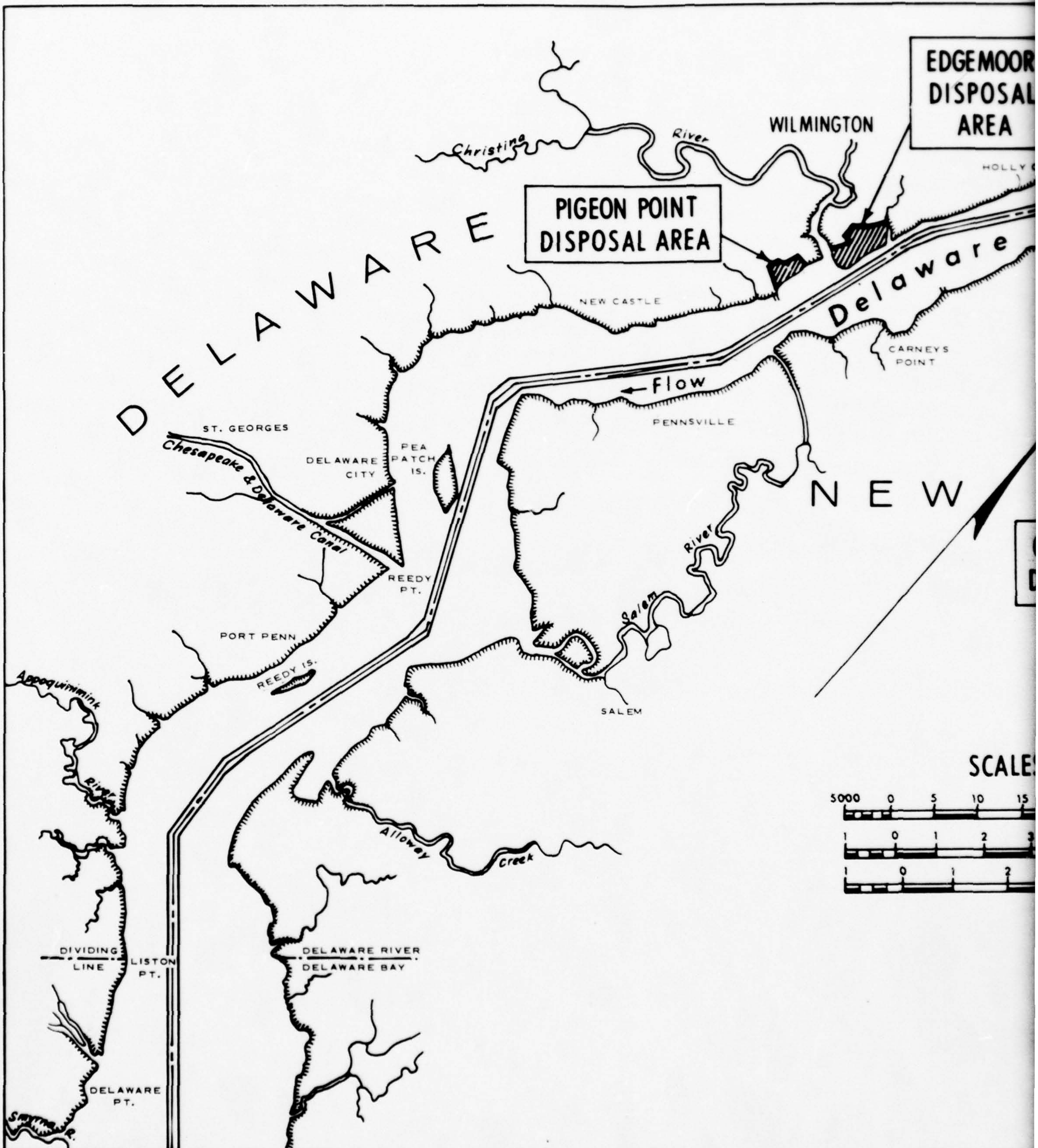
CHESTER-MONDS ISLAND DISPOSAL AREA

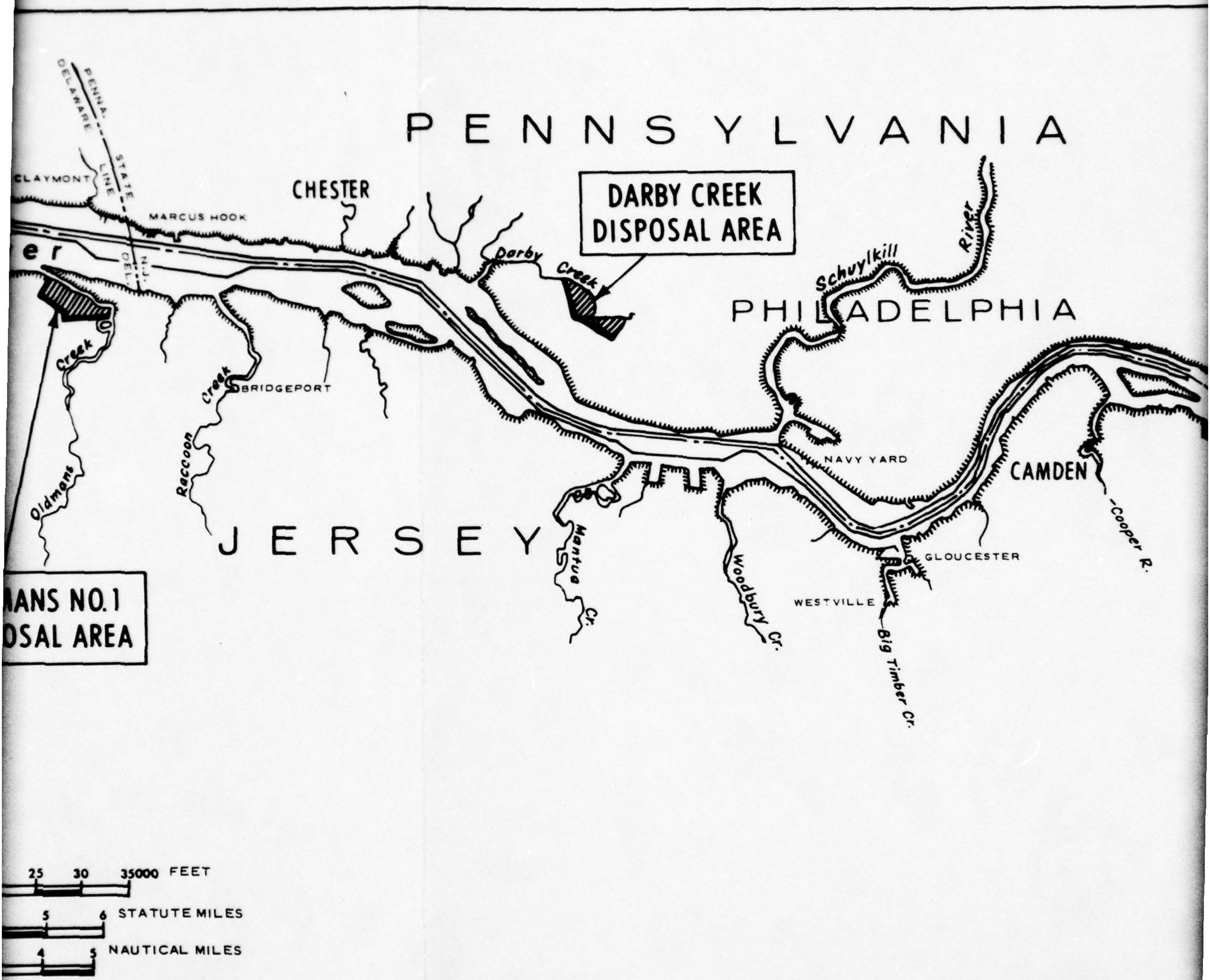
SOIL PROFILES & DIKE SECTIONS

U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

2

PLATE 10


EDGEMOOR
DISPOSAL
AREA
WILMINGTON
Christina River
PIGEON POINT
DISPOSAL AREA
DELAWARE
NEW CASTLE
Delaware
CARNEYS POINT
Flow
PENNSVILLE
ST. GEORGES
Chesapeake & Delaware Canal
DELAWARE CITY
PEA PATCH IS.
NEW
Salem River
REEDY PT.
PORT PENN
REEDY IS.
Appoquinimink River
SALEM
SCALES
5000 0 5 10 15
Alloway Creek
DIVIDING LINE
LISTON PT.
DELAWARE RIVER
DELAWARE BAY
DELAWARE PT.
Smyrna R.



LONG RANGE SPOIL DISPOSAL STU

DELAWARE RIVER DISPOSAL AR
LOCATION MAP

U. S. ARMY ENGINEER DISTRIC
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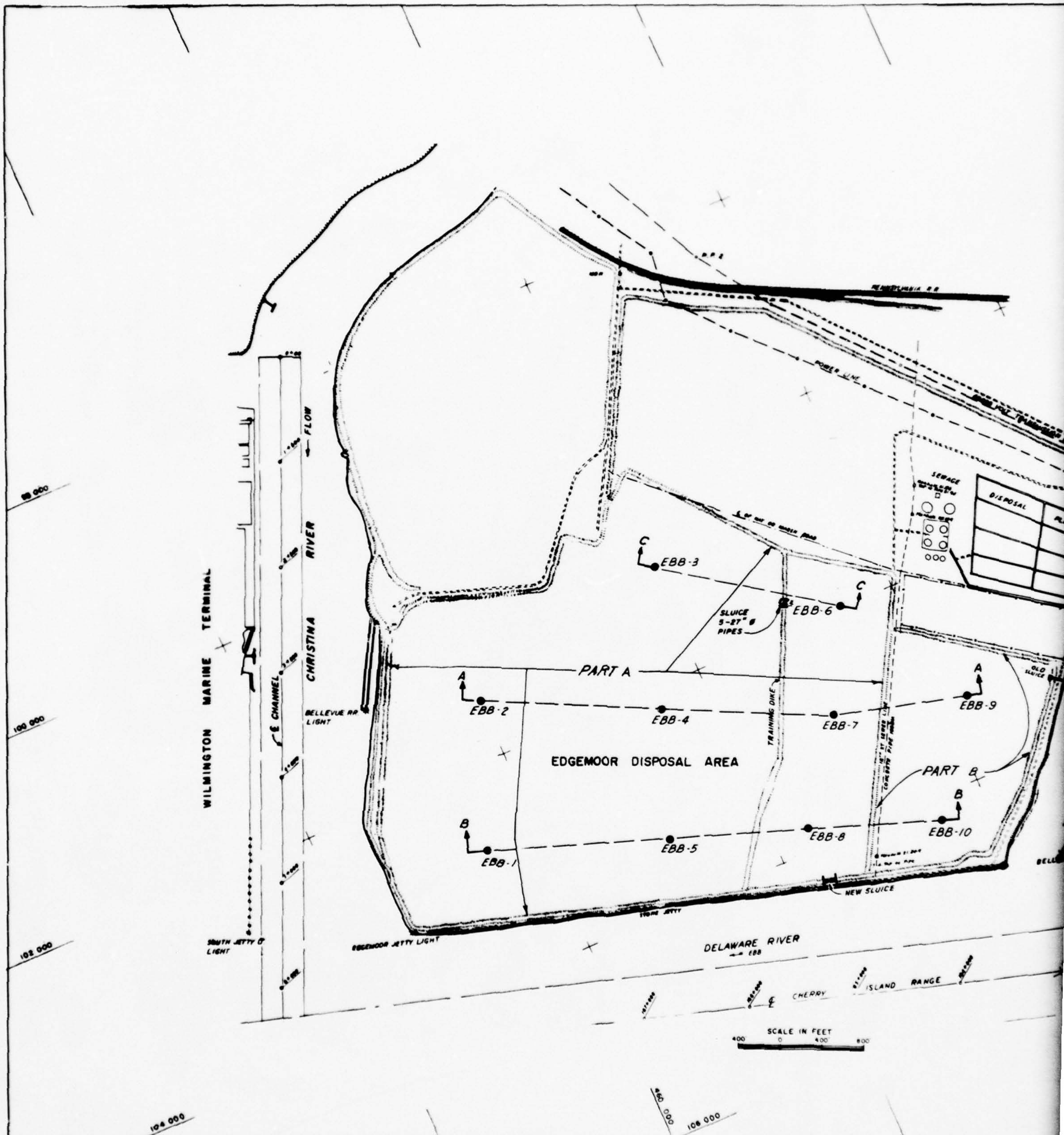
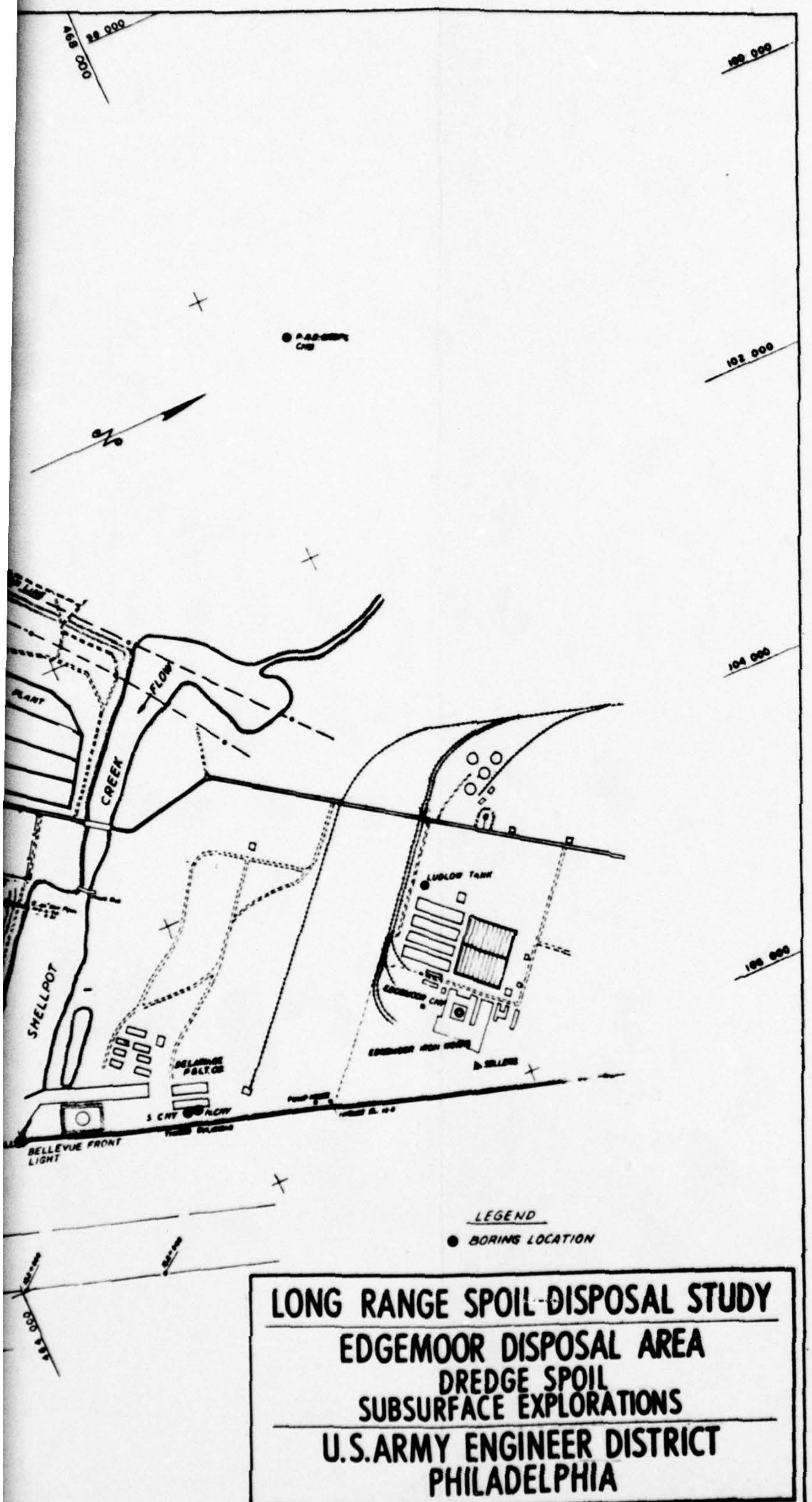

WILMINGTON MARINE TERMINAL
CHRISTINA RIVER
FLOW
BELLEVUE RR LIGHT
SOUTH JETTY LIGHT
EDGEMOOR JETTY LIGHT
DELAWARE RIVER
EBB
CHERRY ISLAND RANGE
EDGEMOOR DISPOSAL AREA
PART A
PART B
SLUICE 5-27" Ø PIPES
TRAINING DIKE
NEW SLUICE
OLD SLUICE
STONE JETTY
POWER LINE
PENNSYLVANIA R.R.
SEWAGE
DISPOSAL
EBB-1
EBB-2
EBB-3
EBB-4
EBB-5
EBB-6
EBB-7
EBB-8
EBB-9
EBB-10
SCALE IN FEET
400 0 400 800
100 000
102 000
104 000
106 000

1



LONG RANGE SPOIL DISPOSAL STUDY

EDGEMOOR DISPOSAL AREA

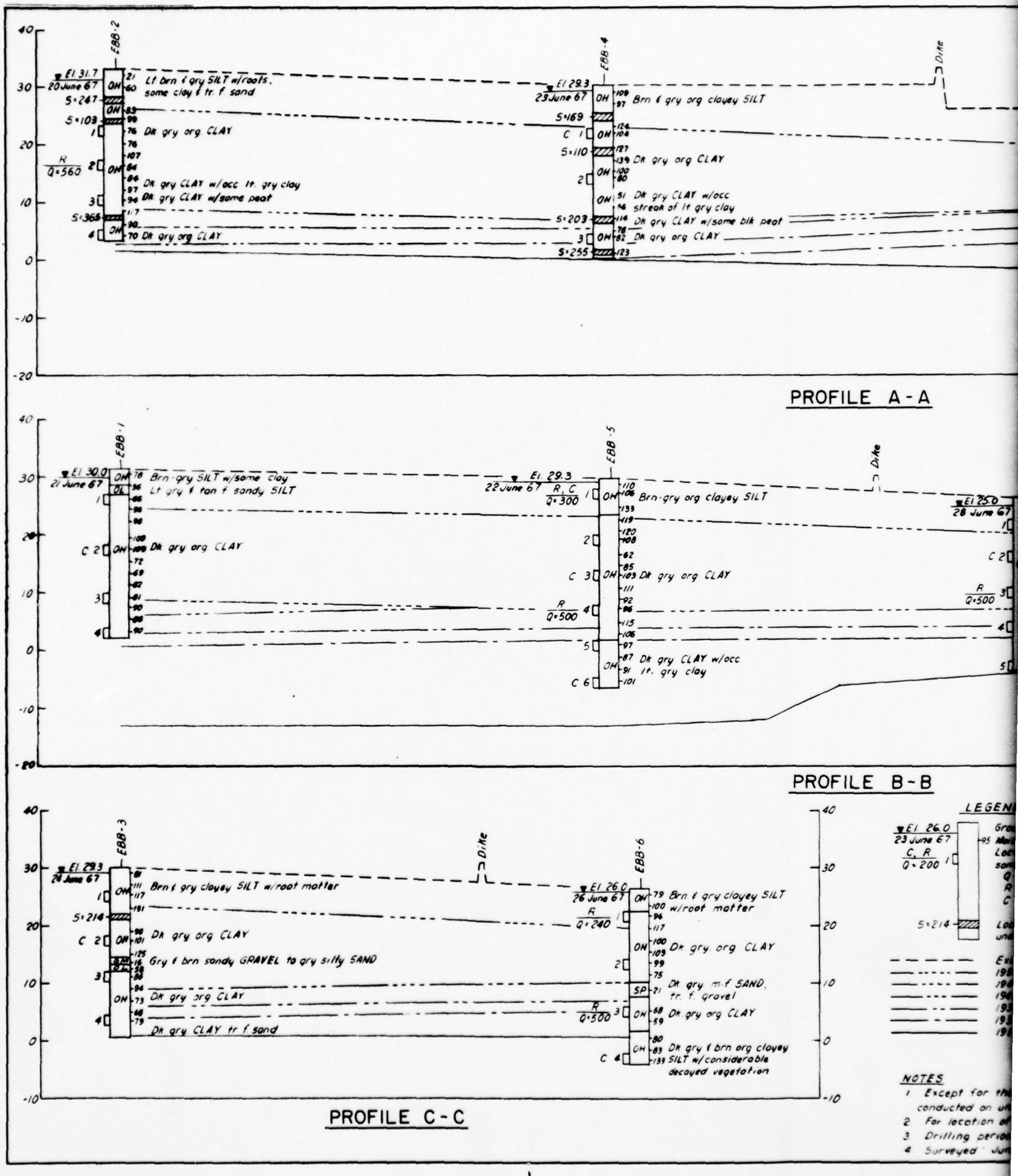
DREDGE SPOIL
SUBSURFACE EXPLORATIONS

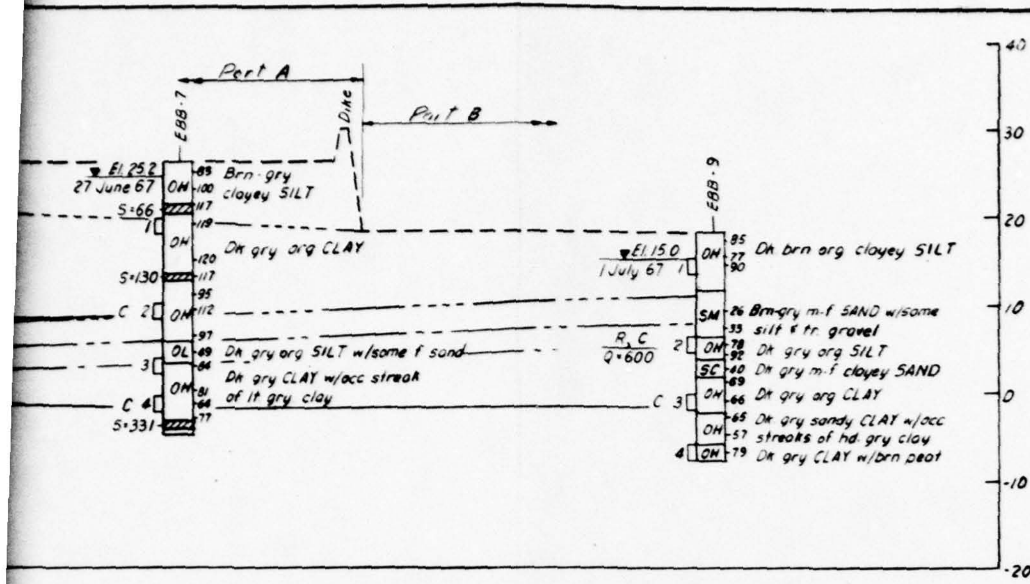
U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

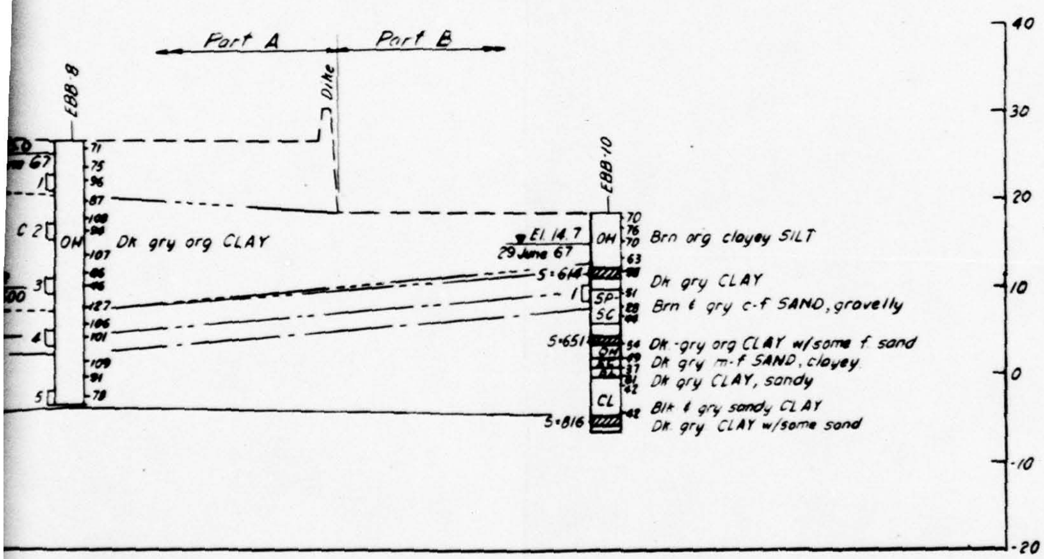
PLATE 12

2

1


EBB-2
El 31.7
20 June 67
Lt brn & gry SILT w/roots, some clay & tr. f. sand
Dk gry org CLAY
Dk gry CLAY w/occ lt. gry clay
Dk gry CLAY w/some peat
Dk gry org CLAY
EBB-4
El 29.3
23 June 67
Brn & gry org clayey SILT
Dk gry org CLAY
Dk gry CLAY w/occ streak of lt gry clay
Dk gry CLAY w/some blk peat
Dk gry org CLAY
Dike
PROFILE A-A
EBB-1
El 30.0
21 June 67
Brn-gry SILT w/some clay
Lt gry & tan f sandy SILT
Dk gry org CLAY
EBB-5
El 29.3
22 June 67
Brn-gry org clayey SILT
Dk gry org CLAY
Dk gry CLAY w/occ lt. gry clay
Dike
El 25.0
28 June 67
PROFILE B-B
EBB-3
El 29.3
24 June 67
Brn & gry clayey SILT w/root matter
Dk gry org CLAY
Gry & brn sandy GRAVEL to gry silty SAND
Dk gry org CLAY
Dk gry CLAY tr f sand
Dike
EBB-6
El 26.0
26 June 67
Brn & gry clayey SILT w/root matter
Dk gry org CLAY
Dk gry m-f SAND, tr. f. gravel
Dk gry org CLAY
Dk gry & brn org clayey SILT w/considerable decayed vegetation
PROFILE C-C
LEGEN
El 26.0
23 June 67
NOTES
1. Except for th conducted on u
2. For location o
3. Drilling perio
4. Surveyed Ju





EGEND

Groundwater elevation and date recorded
95 Moisture content in % of dry weight
Location of undisturbed sample and main tests:
Q - Triaxial shear test and cohesion in p.s.f.
R - Triaxial shear test
C - Consolidation test

Location of vane shear test and undisturbed strength in p.s.f.

Existing ground surface, June 1967
1958 ground surface
1944 ground surface
1942 ground surface
1939 ground surface
1936 ground surface
1911 ground surface prior to disposal

r the "Q" tests other results of the tests
on undisturbed samples are not shown.
on of profiles see plate 12
period: 16 June - 1 July 67
June 67

SCALE IN FEET

HOR. 200 0 200 400

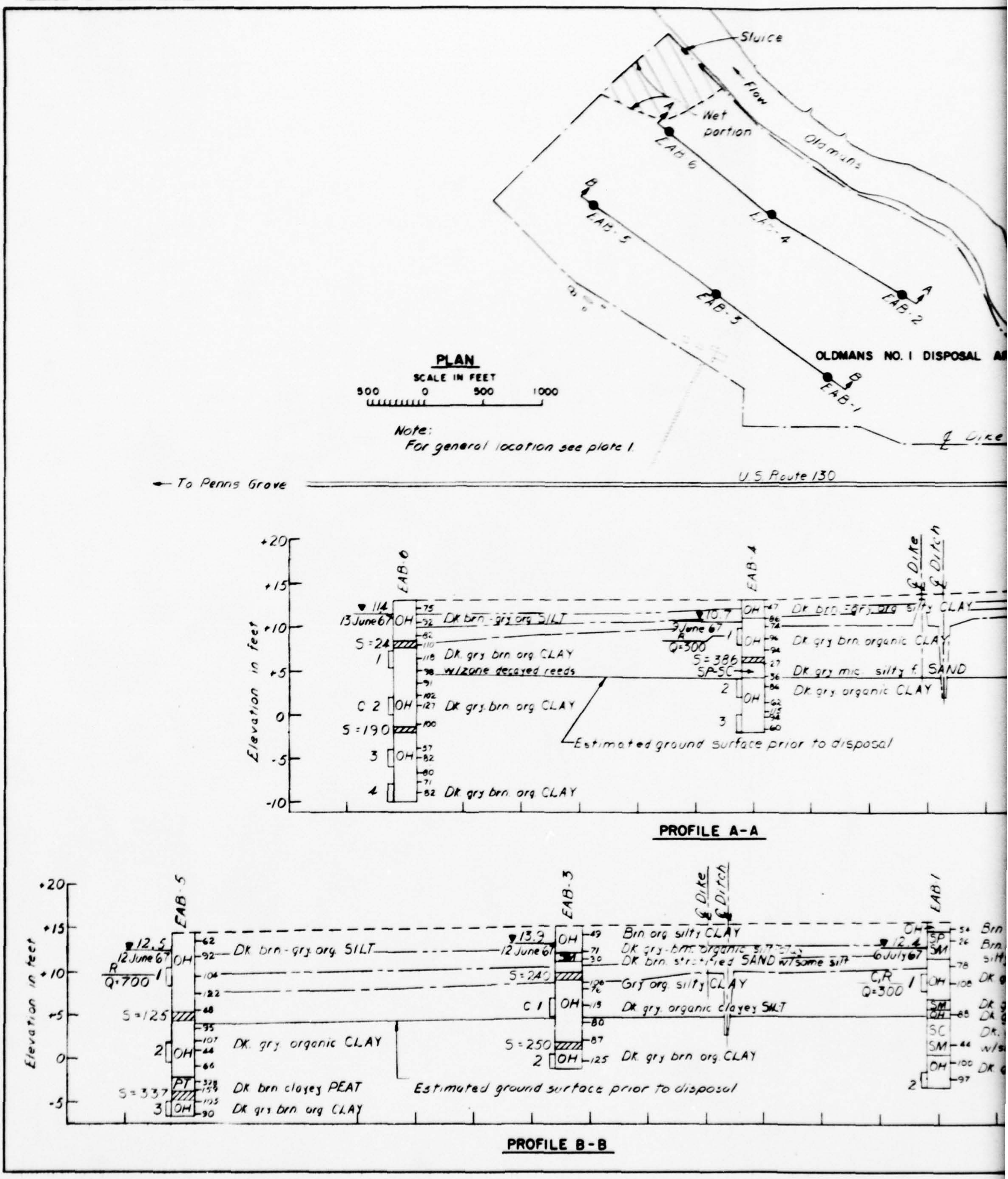
VERT. 10 0 10 20

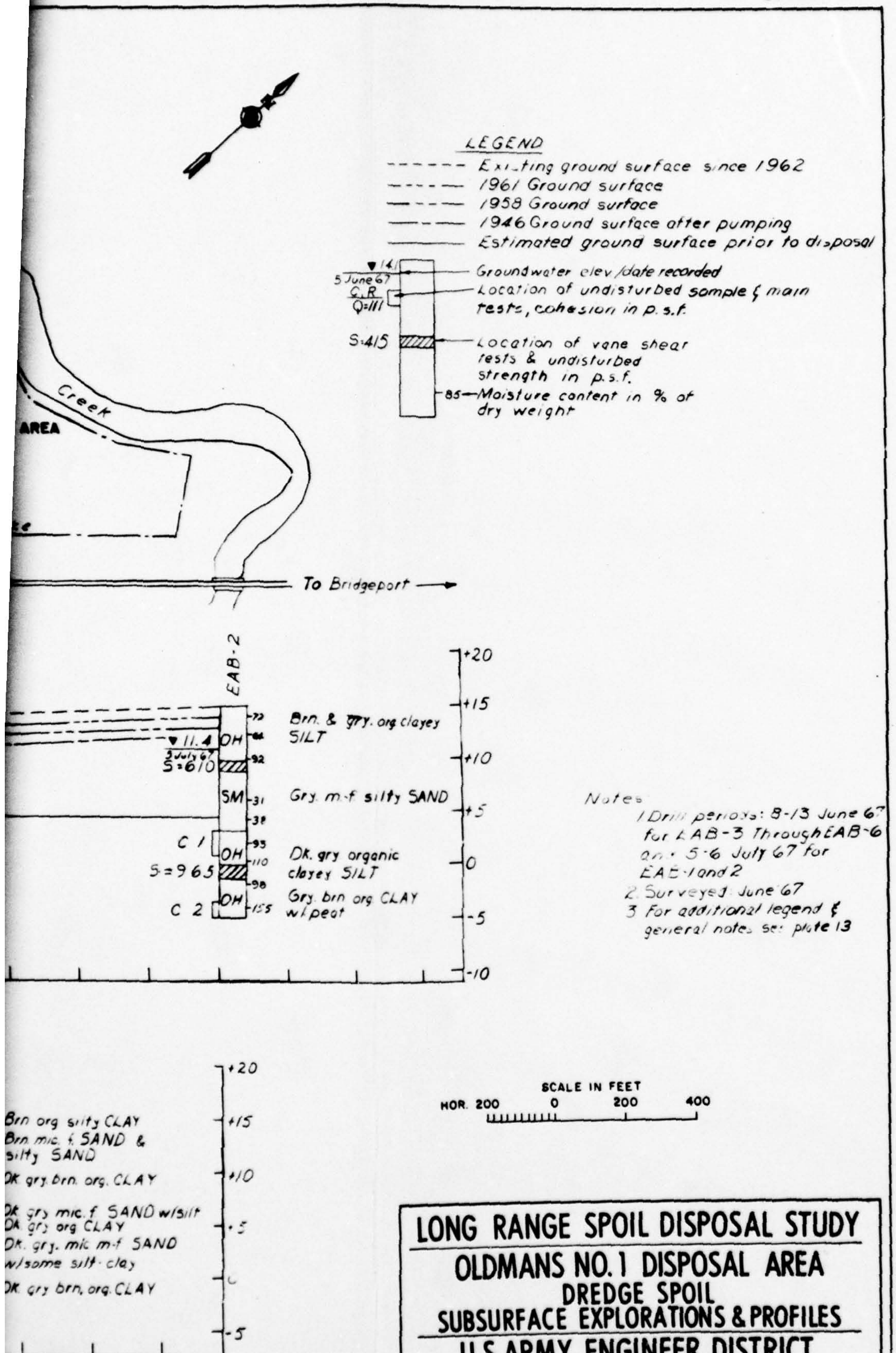
LONG RANGE SPOIL DISPOSAL STUDY

EDGEMOOR DISPOSAL AREA
DREDGE SPOIL
SOIL PROFILES

U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

1 2

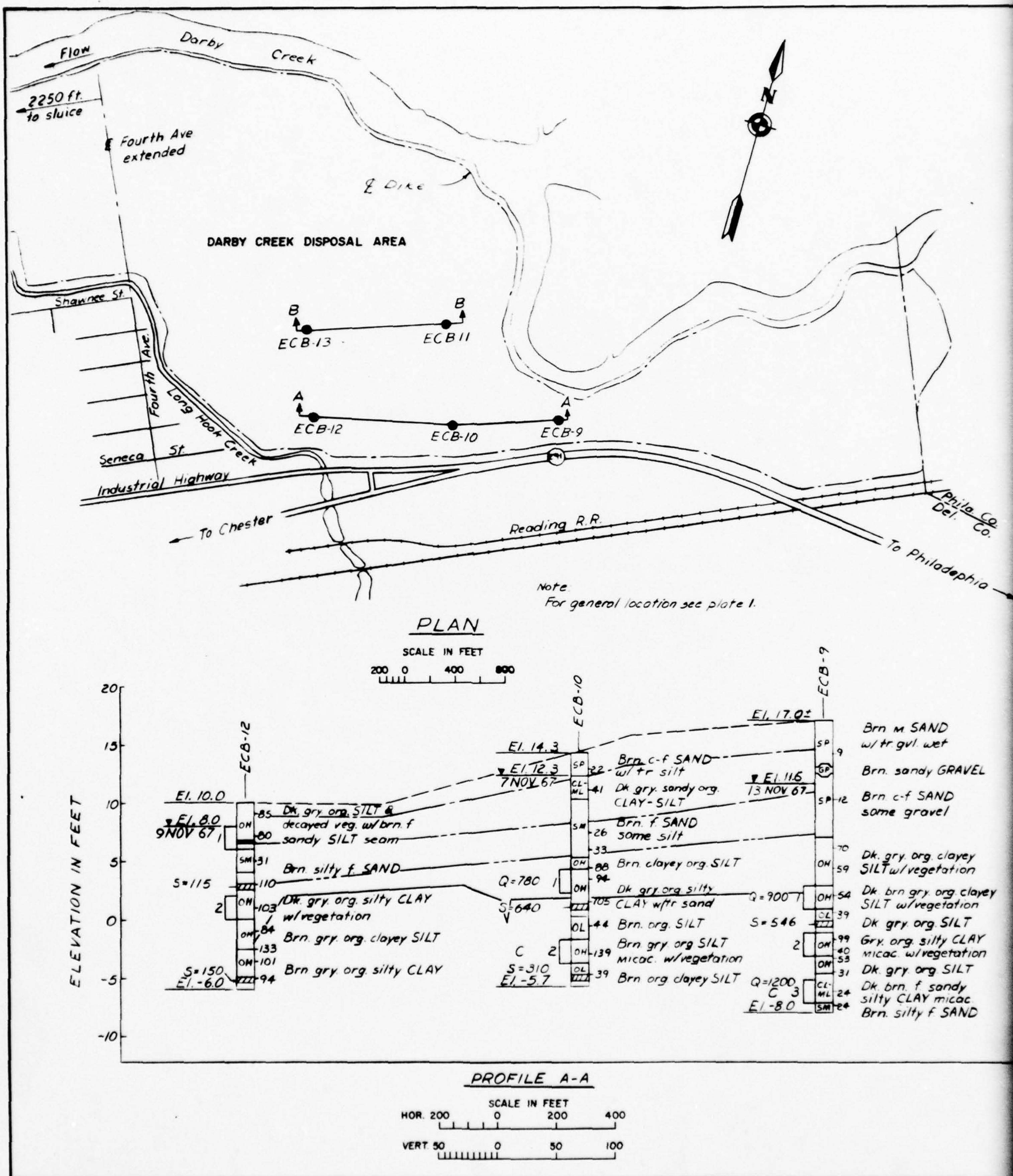

Sluice
Flow
Wet portion
Oldmans
EAB-6
EAB-5
EAB-4
EAB-3
EAB-2
EAB-1
OLDMANS NO. 1 DISPOSAL AR
PLAN
SCALE IN FEET
500 0 500 1000
Note:
For general location see plate 1.
← To Penns Grove
U.S. Route 130
Dike
Elevation in feet
Dk brn-gry org SILT
Dk gry brn org CLAY w/zone decayed reeds
Dk gry brn org CLAY
Dk gry brn org CLAY
Estimated ground surface prior to disposal
Dk brn-gry org silty CLAY
Dk gry brn organic CLAY
Dk gry mic. silty f. SAND
Dk gry organic CLAY
PROFILE A-A
Dk brn-gry org SILT
Dk gry organic CLAY
Dk brn clayey PEAT
Dk gry brn org CLAY
Brn org silty CLAY
Dk gry-brn organic silt
Dk brn stratified SAND w/some silt
Gry org silty CLAY
Dk gry organic clayey SILT
Dk gry brn org CLAY
Estimated ground surface prior to disposal
PROFILE B-B



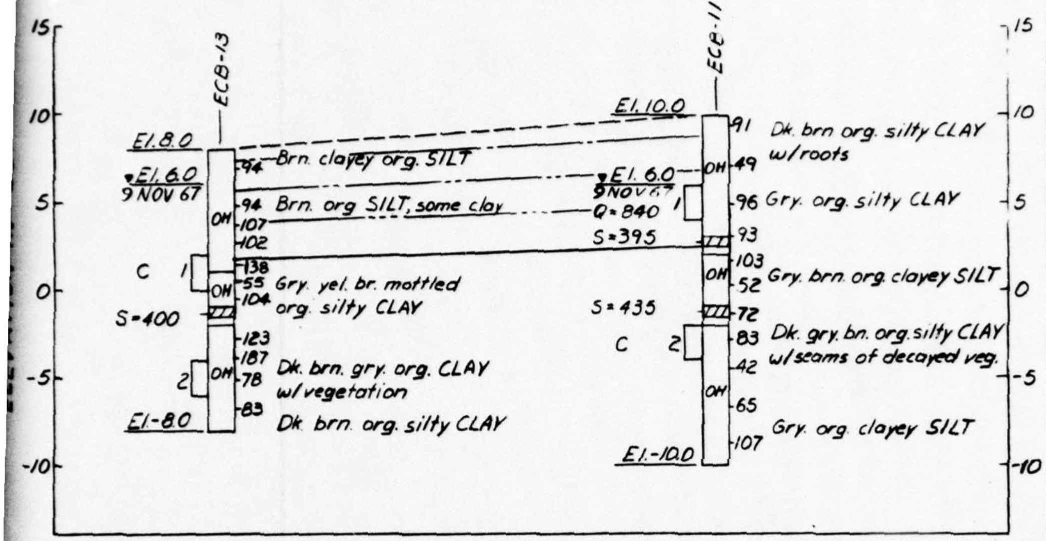
LONG RANGE SPOIL DISPOSAL STUDY

OLDMANS NO. 1 DISPOSAL AREA
DREDGE SPOIL
SUBSURFACE EXPLORATIONS & PROFILES

U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA



Flow
Darby
Creek
2250 ft. to sluice
℄ Fourth Ave extended
℄ Dike
N
DARBY CREEK DISPOSAL AREA
Shawnee St.
Fourth Ave.
Long Hook Creek
B
B
ECB-13
ECB11
A
A
ECB-12
ECB-10
ECB-9
Seneca St.
Industrial Highway
To Chester
Reading R.R.
Phila. Co.
Del. Co.
To Philadelphia
Note:
For general location see plate 1.
PLAN
SCALE IN FEET
200 0 400 800
ELEVATION IN FEET
20
15
10
5
0
-5
-10
ECB-12
El. 10.0
El. 8.0
9 NOV 67
Dk. gry. org. SILT & decayed veg. w/ brn. f sandy SILT seam
Brn. silty f. SAND
S=115
Dk. gry. org. silty CLAY w/vegetation
Brn. gry. org. clayey SILT
Brn. gry. org. silty CLAY
S=150
El. -6.0
ECB-10
El. 14.3
El. 12.3
7 NOV 67
Brn. c-f SAND w/ tr. silt
Dk. gry. sandy org. CLAY-SILT
Brn. f. SAND some silt
Brn. clayey org. SILT
Q=780
Dk. gry. org. silty CLAY w/ tr. sand
S=640
Brn. org. SILT
C
Brn. gry. org. SILT micac. w/vegetation
S=310
El. -5.7
Brn. org. clayey SILT
ECB-9
El. 17.0±
El. 11.6
13 NOV 67
Brn. m. SAND w/ tr. gvl. wet
Brn. sandy GRAVEL
Brn. c-f SAND some gravel
Dk. gry. org. clayey SILT w/vegetation
Q=900
Dk. brn. gry. org. clayey SILT w/vegetation
S=546
Dk. gry. org. SILT
Gry. org. silty CLAY micac. w/vegetation
Dk. gry. org. SILT
Q=1200
C
Dk. brn. f. sandy silty CLAY micac.
El. -8.0
Brn. silty f. SAND
PROFILE A-A
SCALE IN FEET
HOR. 200 0 200 400
VERT. 50 0 50 100

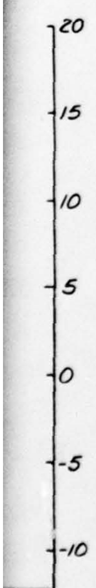


PROFILE B-B

SCALE IN FEET

HOR. 200 0 200 400

VERT. 50 0 50 100



LEGEND

— - — - —	Existing ground surface, since Nov. 66
—— - ——	1964 ground surface
—— - - ——	1959 ground surface
—— - - - ——	1957 ground surface
————	1955 ground surface prior to disposal

Notes:

1. For additional legend and general notes see Plate 13
2. Drilling period 7-10 Nov. 67
3. Surveyed Nov. 67

LONG RANGE SPOIL DISPOSAL STUDY

DARBY CREEK DISPOSAL AREA

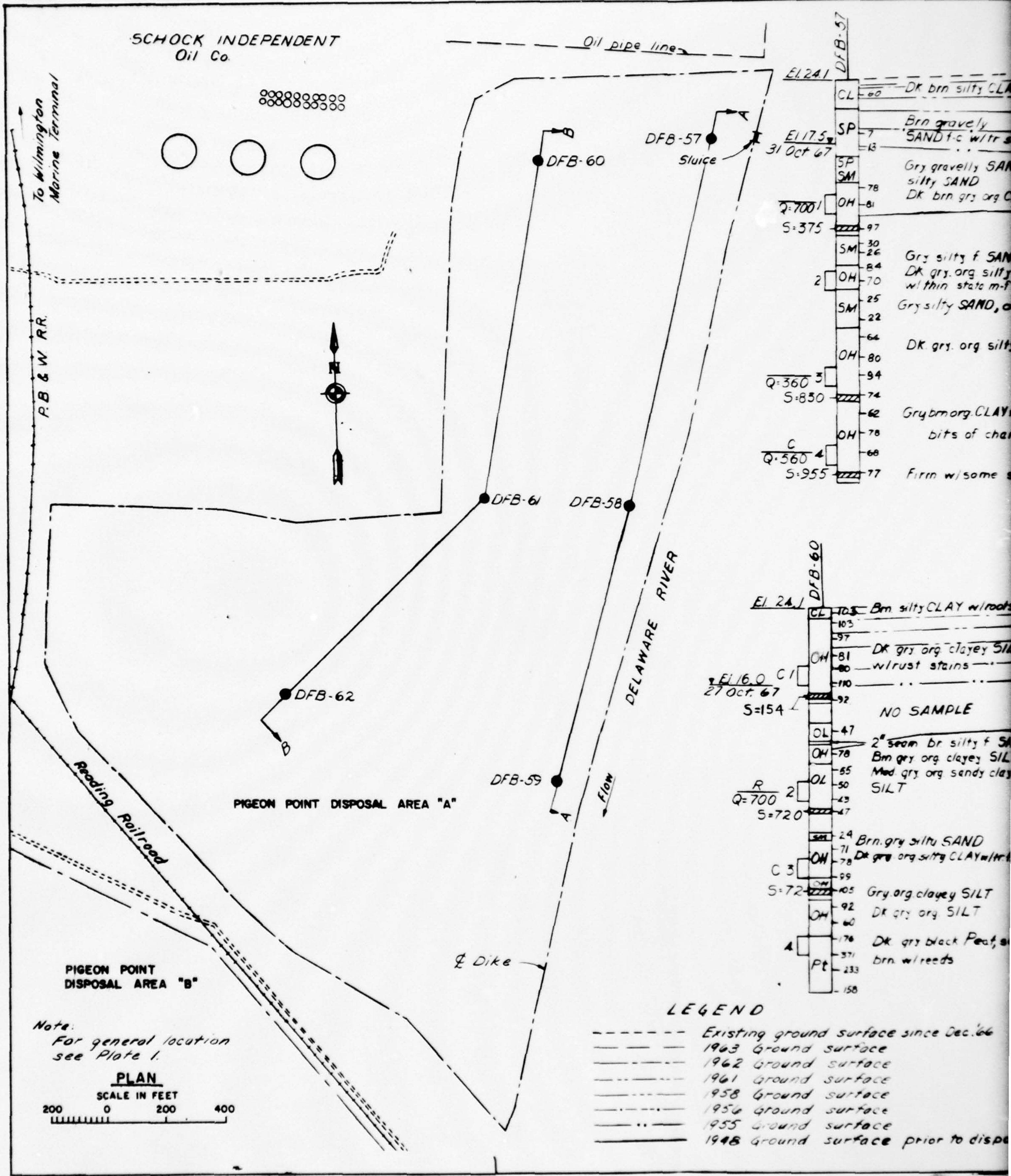
DREDGE SPOIL

SUBSURFACE EXPLORATIONS & PROFILES

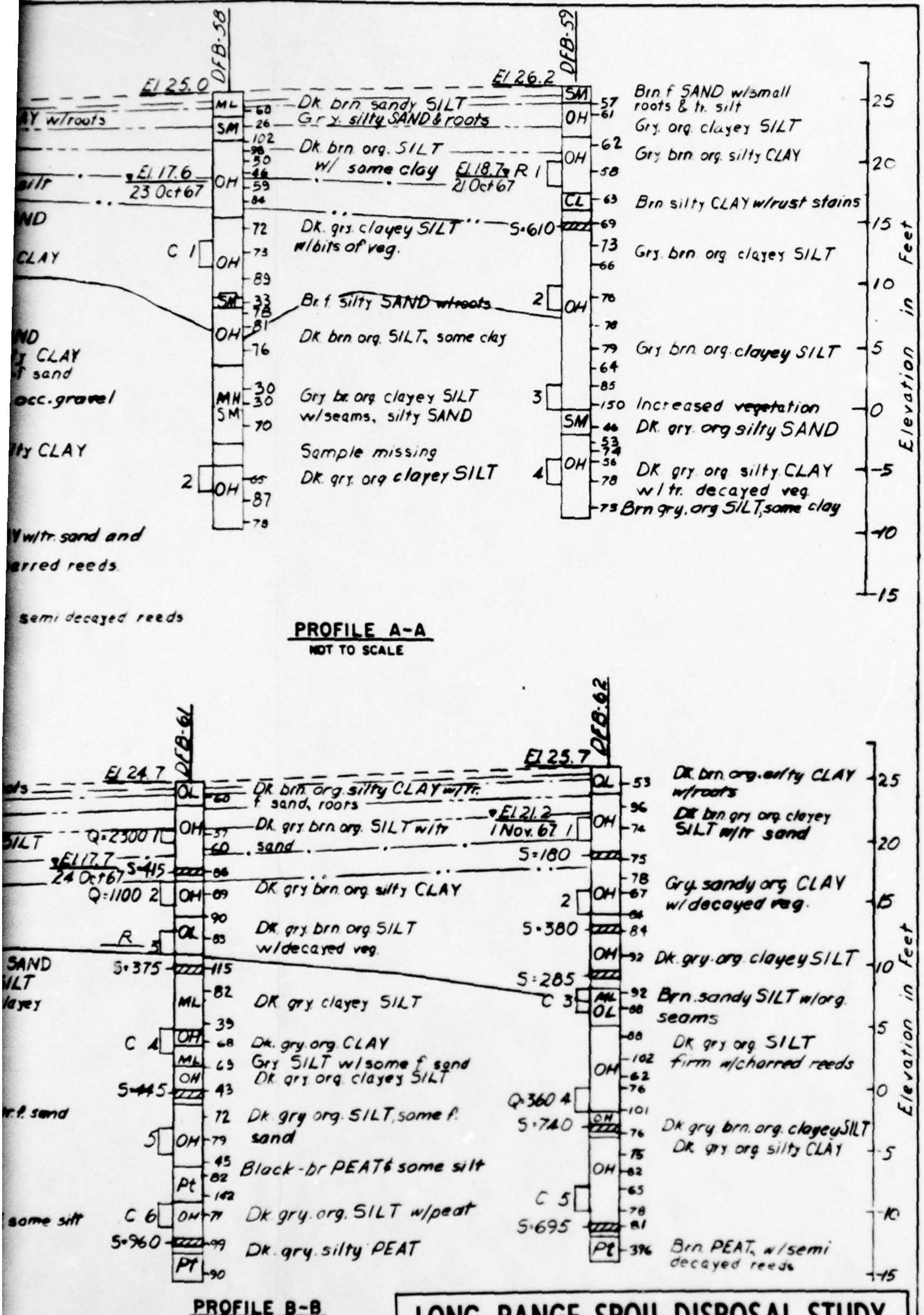
U.S. ARMY ENGINEER DISTRICT

PHILADELPHIA

1 2



SCHOCK INDEPENDENT
Oil Co.
Oil pipe line
To Wilmington Marine Terminal
P.B. & W. R.R.
N
DFB-57
Sluice
DFB-60
DFB-61
DFB-58
DFB-62
DFB-59
DELAWARE RIVER
Flow
Reading Railroad
PIGEON POINT DISPOSAL AREA "A"
PIGEON POINT DISPOSAL AREA "B"
℄ Dike
Note:
For general location see Plate 1.
PLAN
SCALE IN FEET
200 0 200 400
El. 24.1
El. 17.5
31 Oct 67
Q=700
S=375
Q=360
S=850
C
Q=560
S=955
CL
SP
SP SM
OH
SM
Dk brn silty CLA
Brn gravely SAND f-c w/tr
Gry gravelly SAN
silty SAND
Dk brn gry org C
Gry silty f SAN
Dk gry. org silty
w/ thin strata m-f
Gry silty SAND, c
Dk gry. org silty
Gry brn org. CLAY
bits of cha
Firm w/some
El. 24.1
El. 16.0
27 Oct. 67
S=154
R
Q=700
S=720
C 3
S=72
OL
Pt
Brn. silty CLAY w/roots
Dk gry org clayey SIL
w/rust stains
NO SAMPLE
2" seam br. silty f SA
Brn gry org clayey SIL
Med. gry org sandy clay
SILT
Brn. gry silty SAND
Dk gry org silty CLAY w/tr.
Gry org clayey SILT
Dk gry org SILT
Dk gry black Peat,
brn. w/ reeds
LEGEND
Existing ground surface since Dec. '66
1963 Ground surface
1962 Ground surface
1961 Ground surface
1958 Ground surface
1956 Ground surface
1955 Ground surface
1948 Ground surface prior to dispo



Notes:
1. Drilling period: 21 Oct - 3 Nov 67
2. Surveyed: Oct 67
3. For additional legend & general notes see Plate 3.

LONG RANGE SPOIL DISPOSAL STUDY

PIGEON POINT DISPOSAL AREA
DREDGE SPOIL
SUBSURFACE EXPLORATIONS & PROFILES

U.S. ARMY ENGINEER DISTRICT
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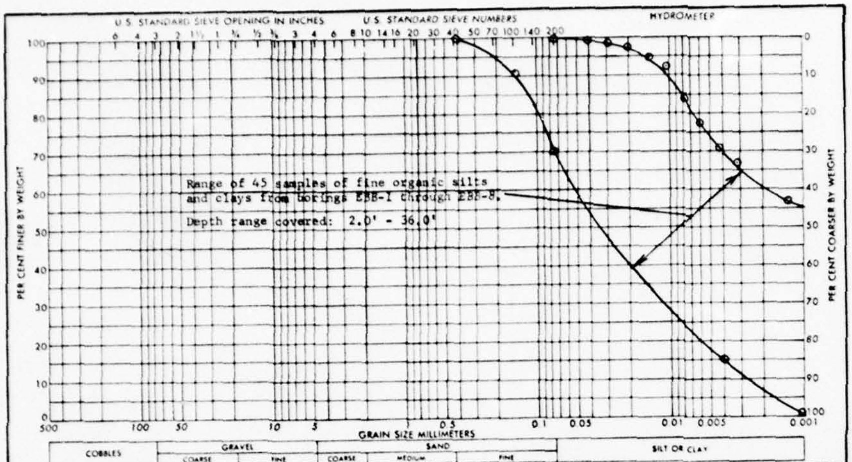
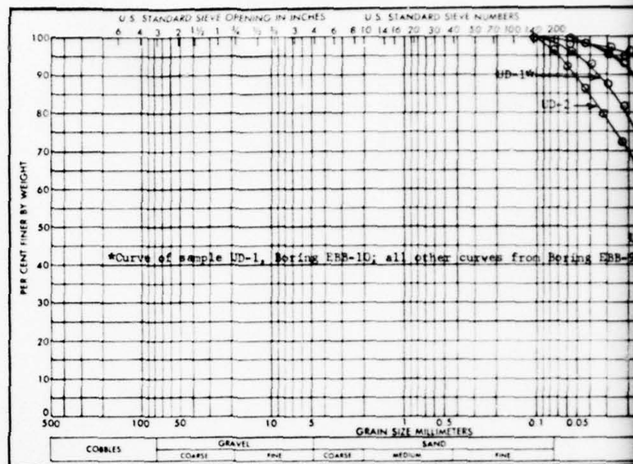
2



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT	Delaware River Disposal Areas Study
AREA	Edgemoor Part A
BORING NO	EBB-1 through EBB-8
DATE	October 1967

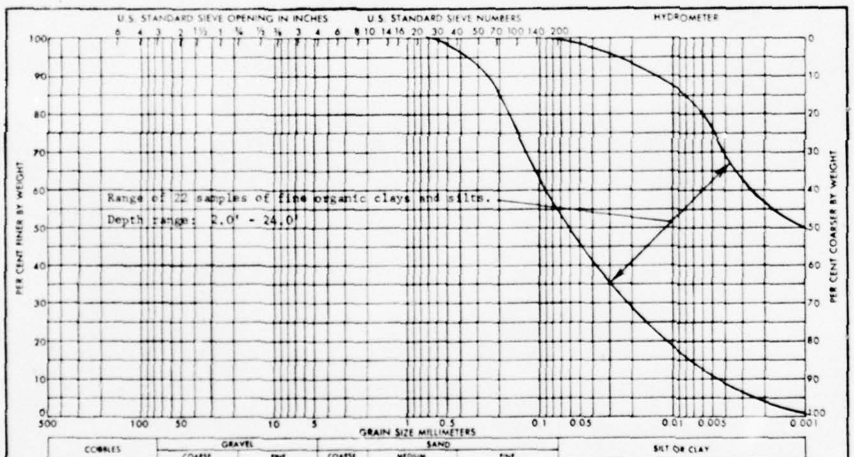
GRADATION CURVES



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI
UD-1	4.0' - 6.0'	Organic CLAY (OH)		116	50	66
UD-2	12.0' - 14.0'	Organic CLAY (OH)		89	49	40
UD-3	18.0' - 20.0'	Organic CLAY (OH)		96	33	53
UD-4	24.0' - 26.0'	Organic CLAY (OH)		109	42	67
UD-1*	8.0' - 10.0'	Organic SILT (OH)		81	42	39

PROJECT	De
	Di
AREA	Ed
BORING NO	EB
DATE	Oc

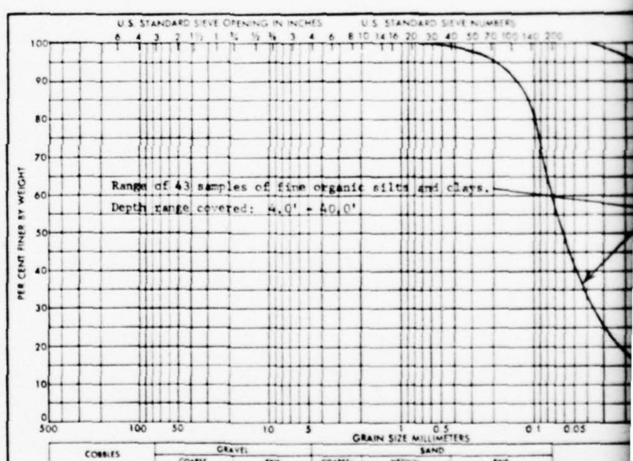
GRADATION CURVES



SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

PROJECT	Delaware River Disposal Areas Study
AREA	Darby Creek
BORING NO	ECB-9 thru ECB-13
DATE	Feb - Mar 1968

GRADATION CURVES

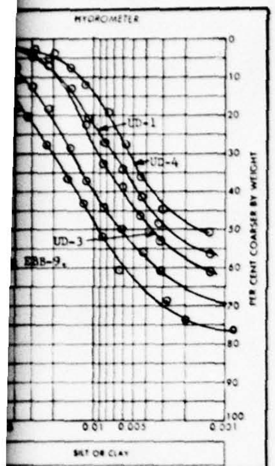


SAMPLE NO	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

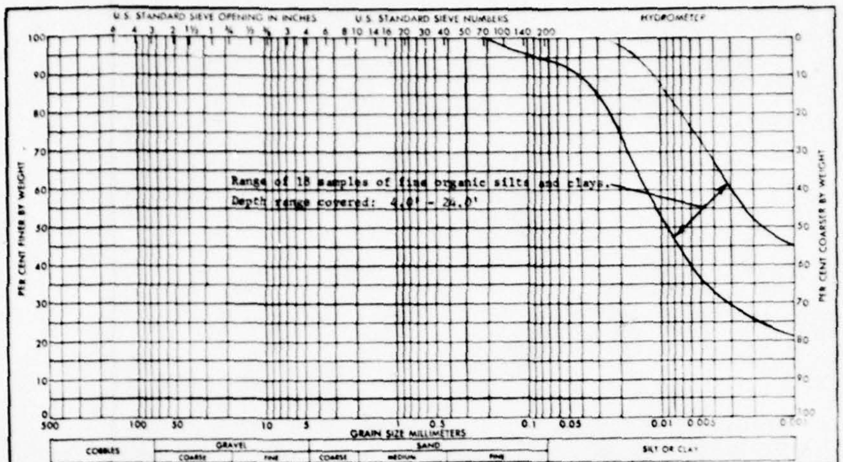
PROJECT	D
	S
AREA	F
BORING NO	D
DATE	F

GRADATION CURVES

MECHANICAL ANALYSIS ENVEL



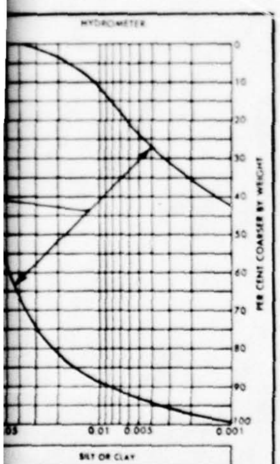
PROJECT Delaware River
Disposal Areas Study
AREA Edgemoor Part B
BORING NO EBB-9 and EBB-10
DATE October 1967



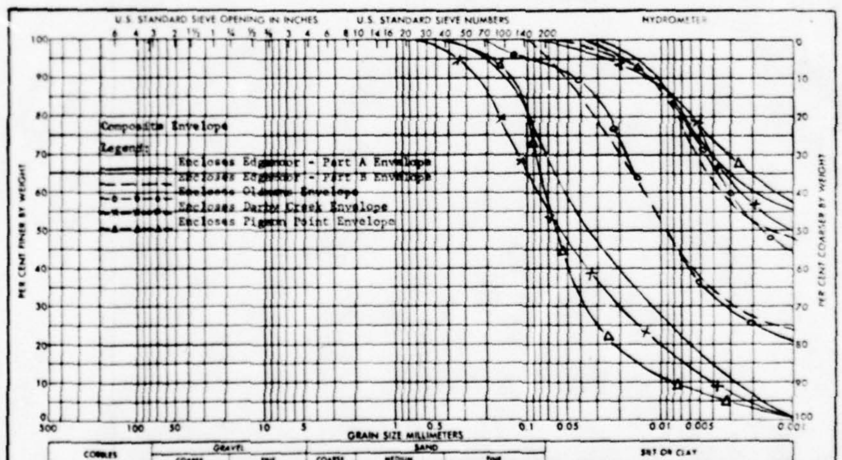
SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

GRADATION CURVES

PROJECT Delaware River
Disposal Areas Study
AREA Oldmans No. 1
BORING NO EAB-1 thru EAB-6
DATE Sep - Oct 1967



PROJECT Delaware River
Disposal Areas Study
AREA Pigeon Point
BORING NO DFB-57 thru DFB-62
DATE Feb - Mar 1968



SAMPLE NO.	ELEV OR DEPTH	CLASSIFICATION	NAT W%	LL	PL	PI

GRADATION CURVES

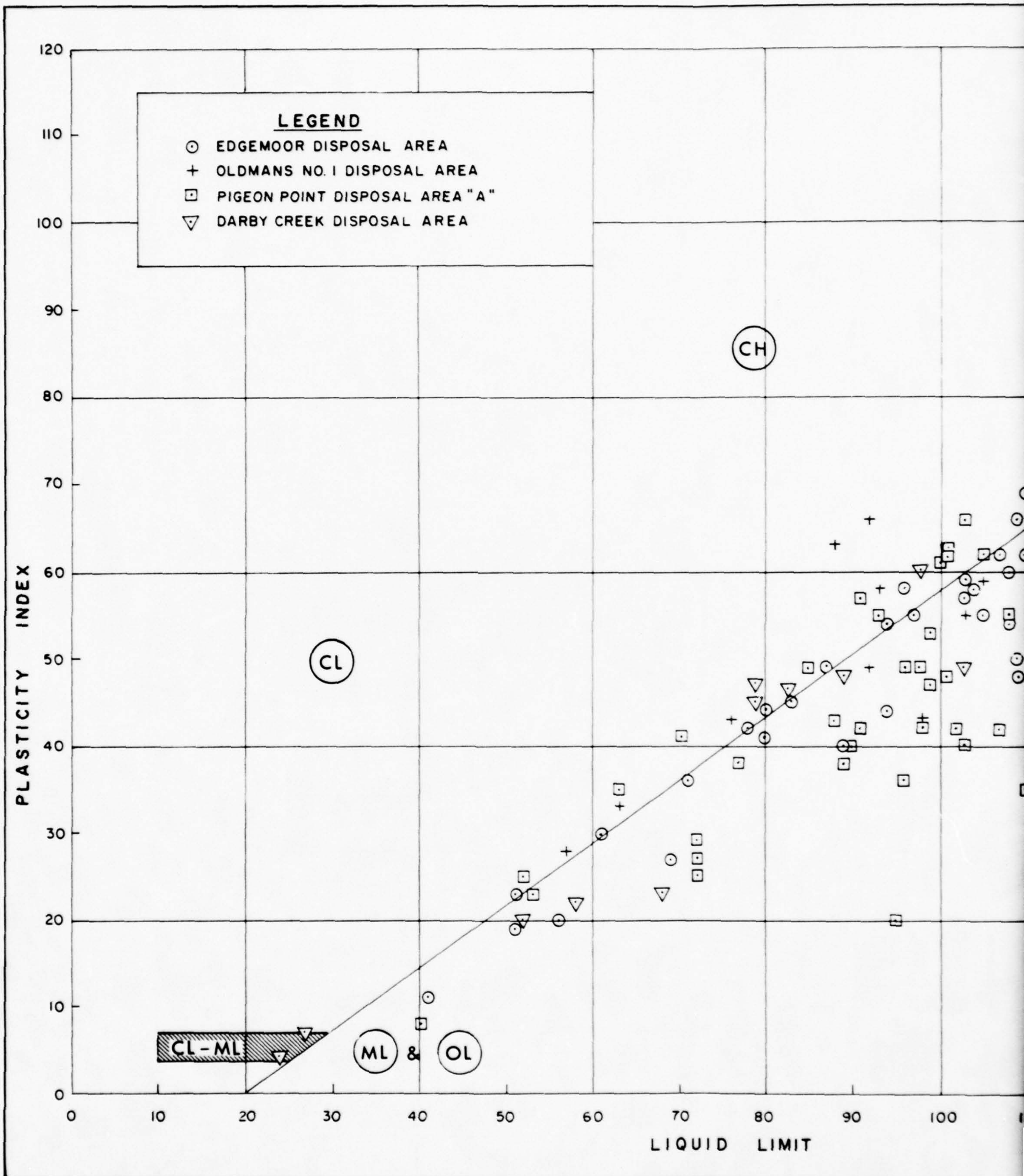
PROJECT Delaware River
Disposal Areas Study
AREA All Four Areas
BORING NO
DATE Sep 1967 - Mar 1968

VELOPES

LONG RANGE SPOIL DISPOSAL STUDY

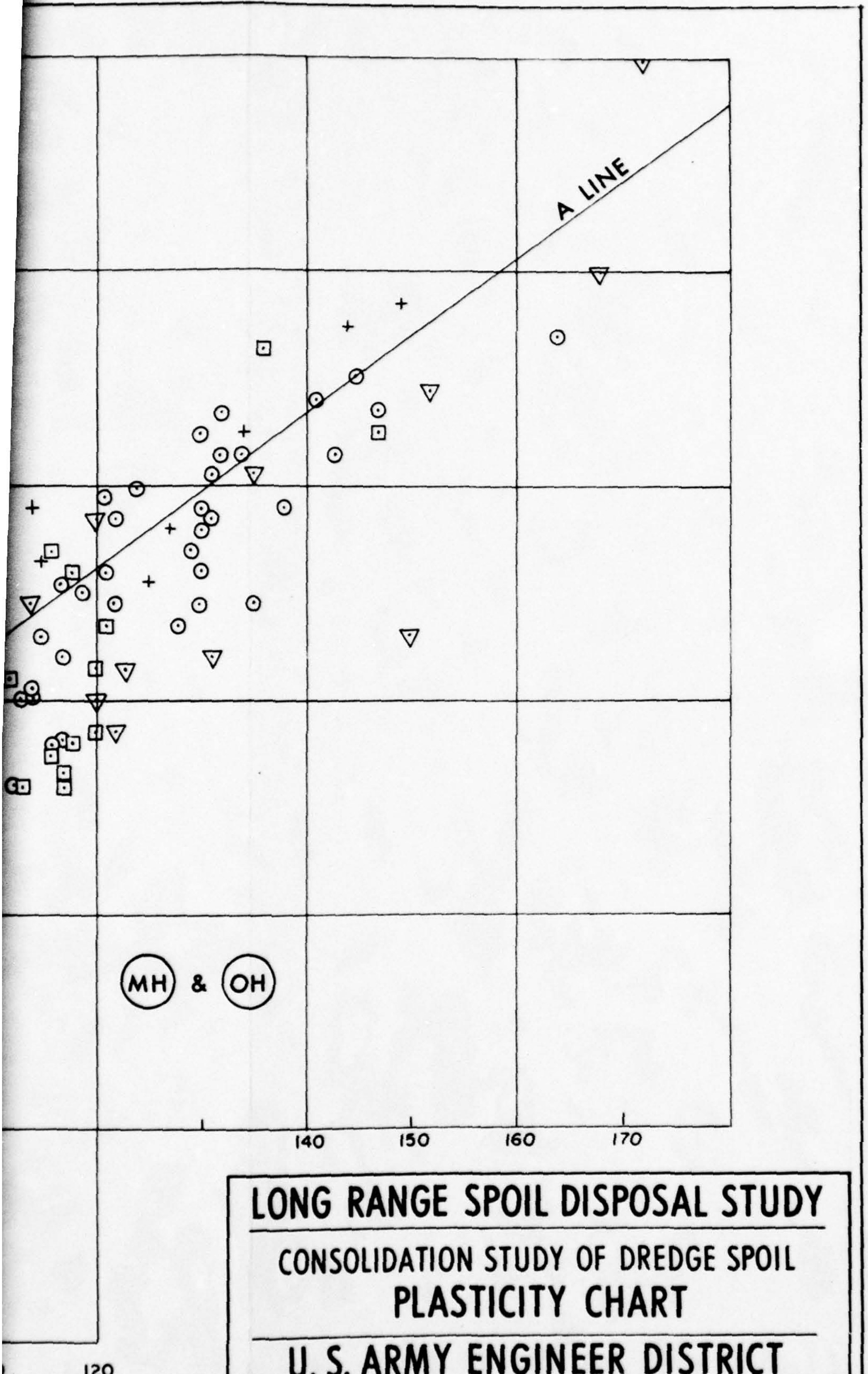
DELAWARE RIVER DISPOSAL AREAS
GRADATION CURVES

U.S.ARMY ENGINEER DISTRICT
2 PHILADELPHIA



LEGEND
EDGEMOOR DISPOSAL AREA
OLDMANS NO. 1 DISPOSAL AREA
PIGEON POINT DISPOSAL AREA "A"
DARBY CREEK DISPOSAL AREA
CH
CL
CL-ML
ML
&
OL
PLASTICITY INDEX
LIQUID LIMIT
0
10
20
30
40
50
60
70
80
90
100
110
120

1



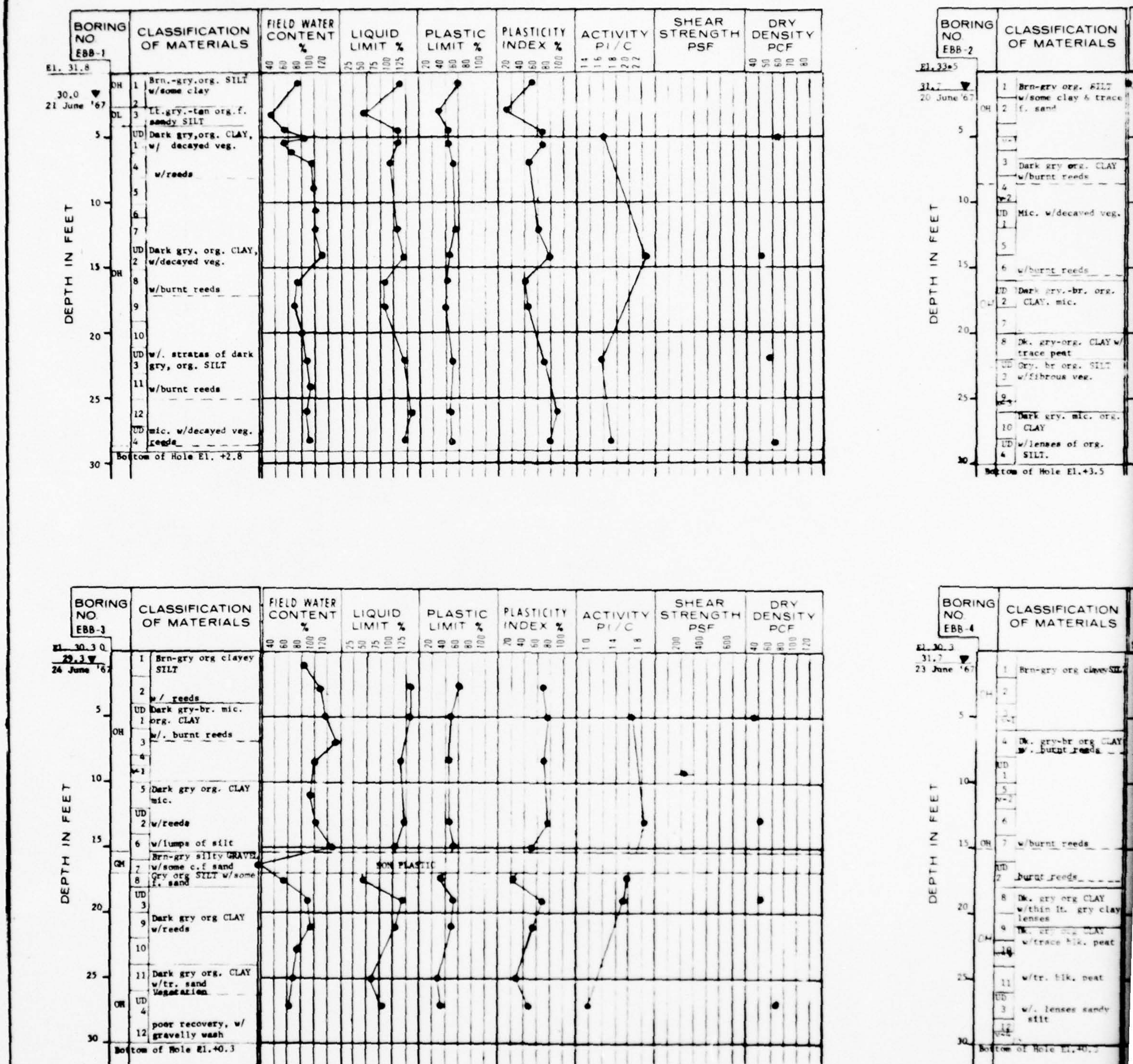
LONG RANGE SPOIL DISPOSAL STUDY

CONSOLIDATION STUDY OF DREDGE SPOIL

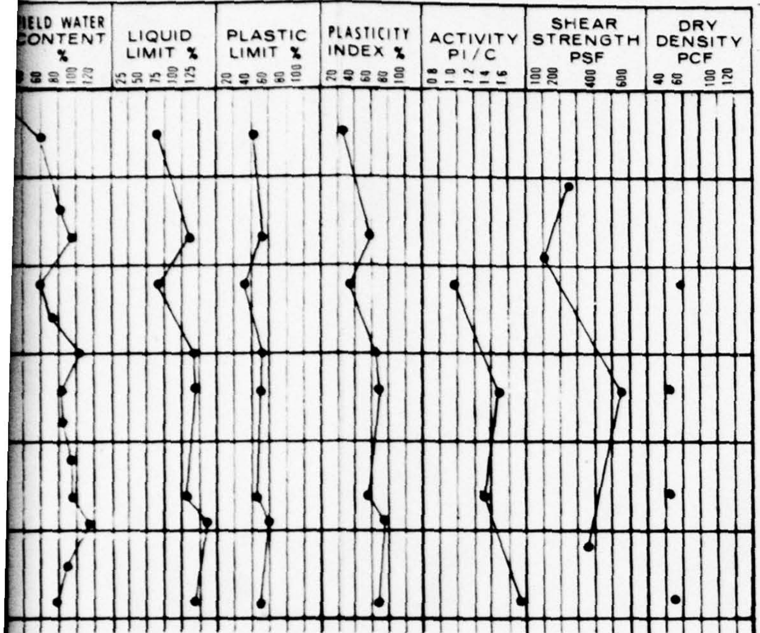
PLASTICITY CHART

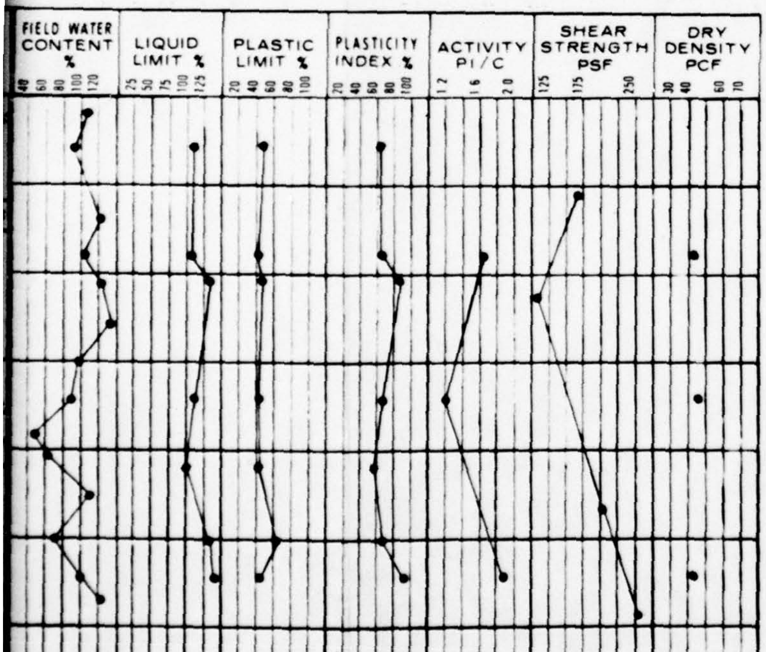
U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

2



BORINGS: EBB-1,2,3,4





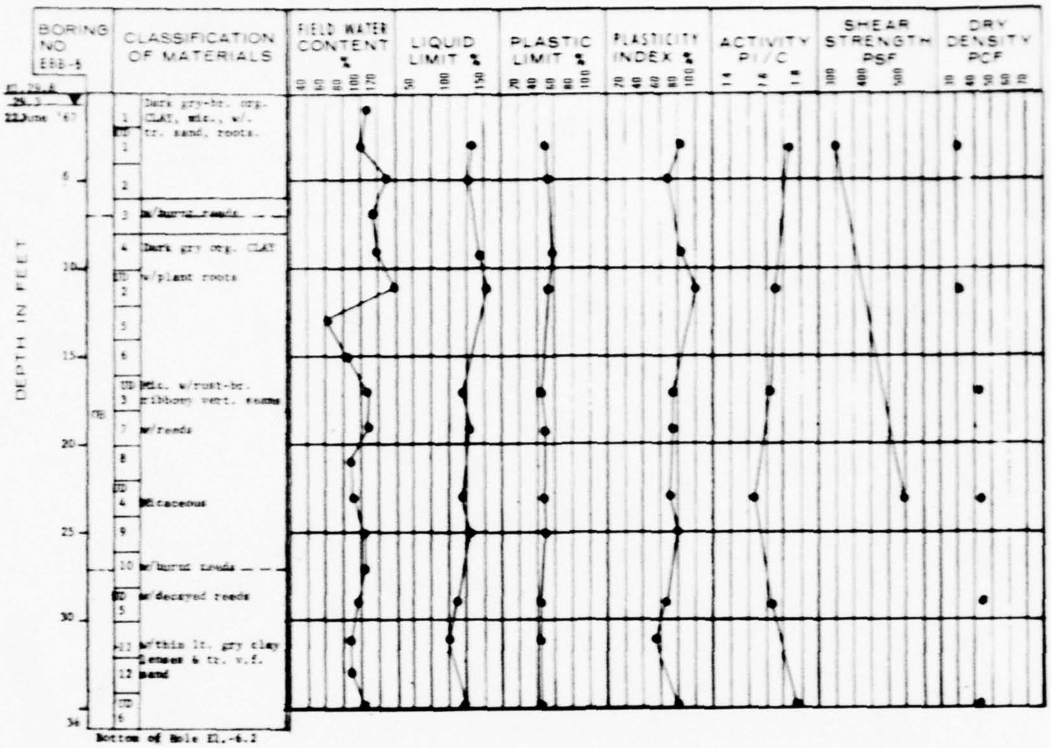
LONG RANGE SPOIL DISPOSAL STUDY

EDGEMOOR DISPOSAL AREA
LOGS OF PHYSICAL PROPERTIES

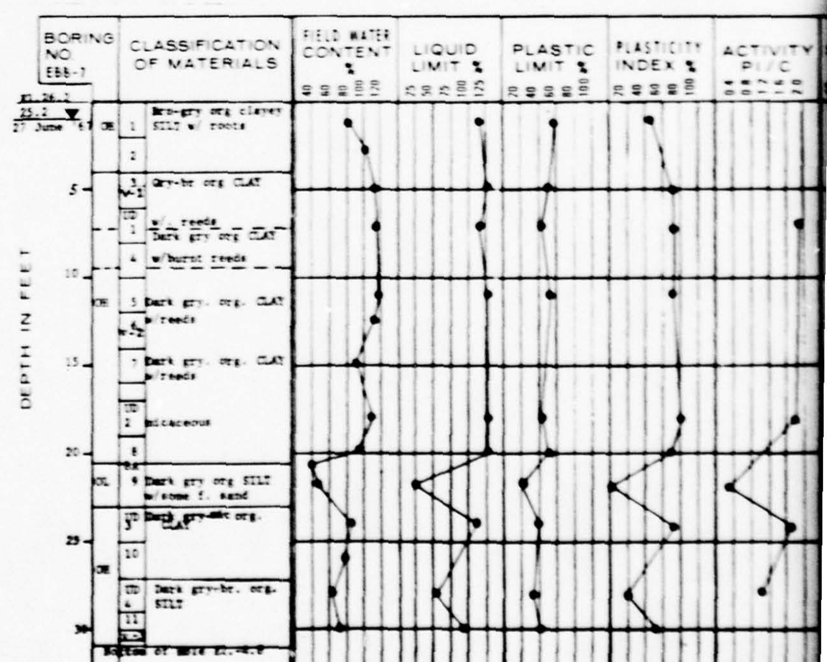
U. S. ARMY ENGINEER DISTRICT
2 PHILADELPHIA

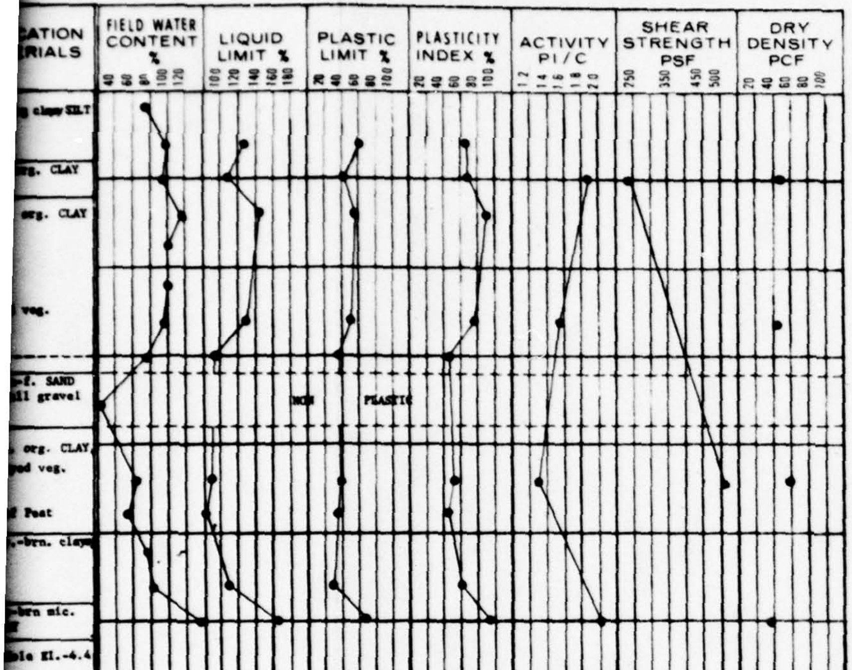
PLATE 19

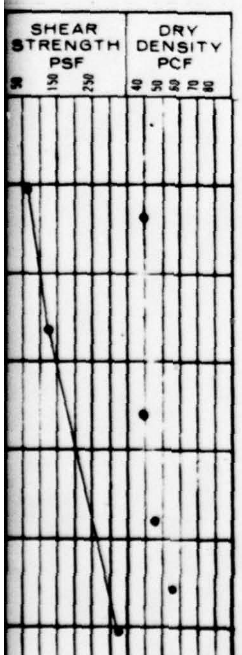
1


BORING NO. EBB-6
CLASSIFICATION OF MATERIALS
FIELD WATER CONTENT %
LIQUID LIMIT %
PLASTIC LIMIT %
PLASTICITY INDEX %
ACTIVITY PI/C
SHEAR STRENGTH PSF
DRY DENSITY PCF
DEPTH IN FEET
Dark gry-br. org. CLAY, mic., w/ tr. sand, roots.
Dark gry org. CLAY
w/plant roots
w/reeds
Micaceous
w/burnt reeds
w/decayed reeds
Bottom of Hole El.-6.2


BORING NO. EBB-8
DEPTH IN FEET
Bottom of


BORING NO. EBB-7
CLASSIFICATION OF MATERIALS
FIELD WATER CONTENT %
LIQUID LIMIT %
PLASTIC LIMIT %
PLASTICITY INDEX %
ACTIVITY PI/C
DEPTH IN FEET
27 June '67
Brn-gry org clayey SILT w/ roots
Gry-br org CLAY
w/ reeds
Dark gry org CLAY
w/burnt reeds
Dark gry. org. CLAY w/reeds
Dark gry. org. CLAY w/reeds
Micaceous
Dark gry org SILT w/some f. sand
Dark gry-br. org. SILT





BORINGS: EBB-5,6,7

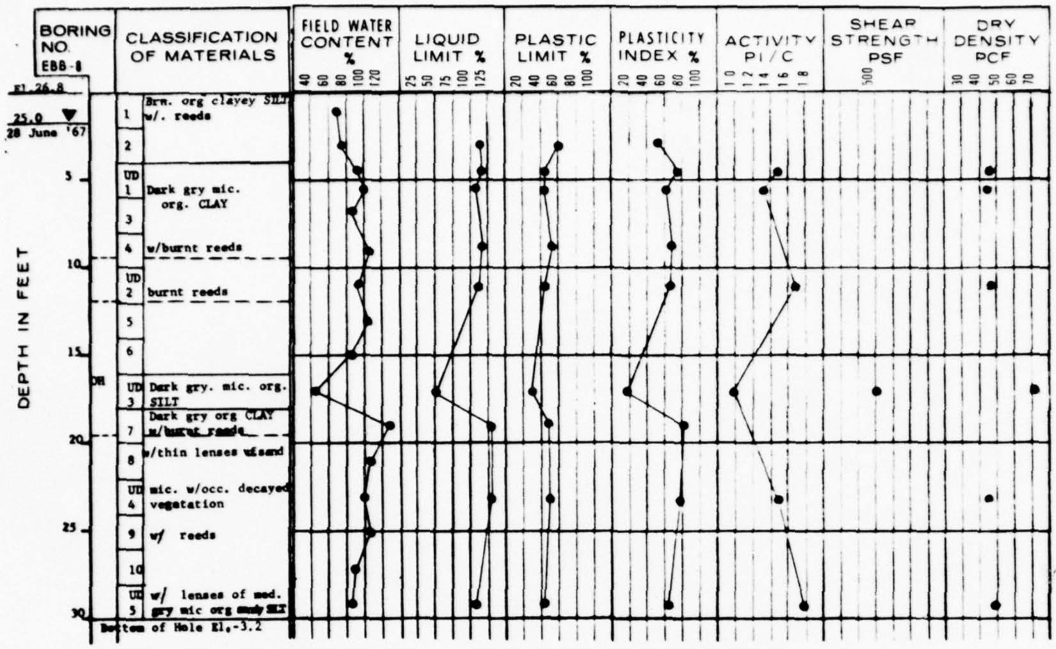
LONG RANGE SPOIL DISPOSAL STUDY

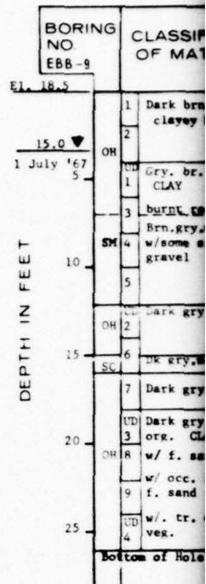
EDGEMOOR DISPOSAL AREA
LOGS OF PHYSICAL PROPERTIES

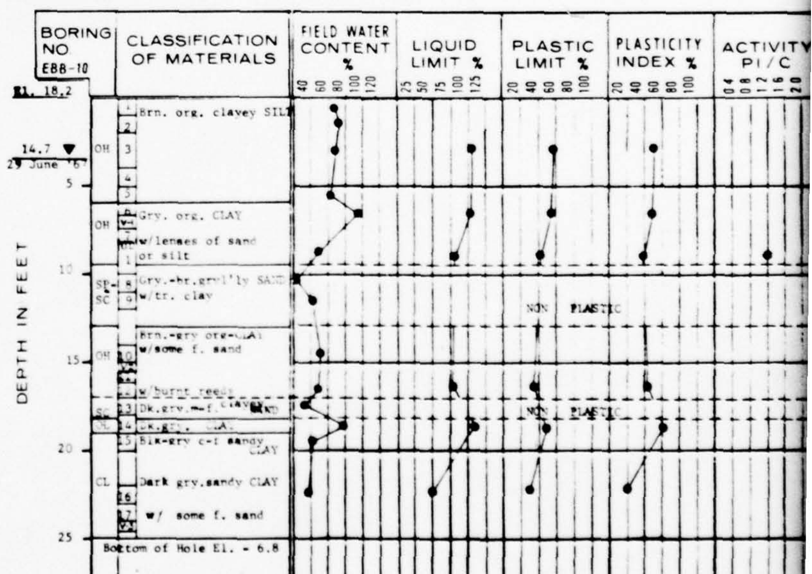
U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

2

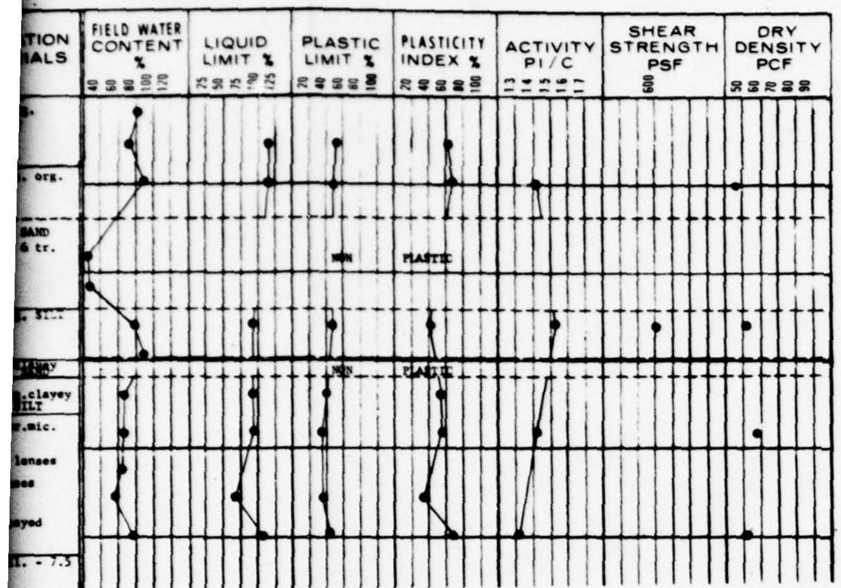
PLATE 20

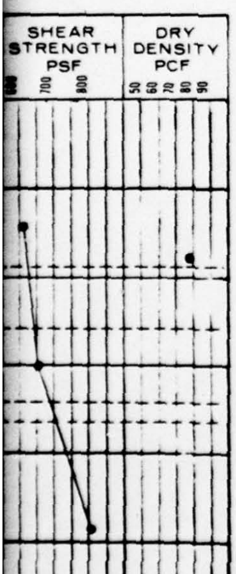






BORINGS: EBB-8,9,10



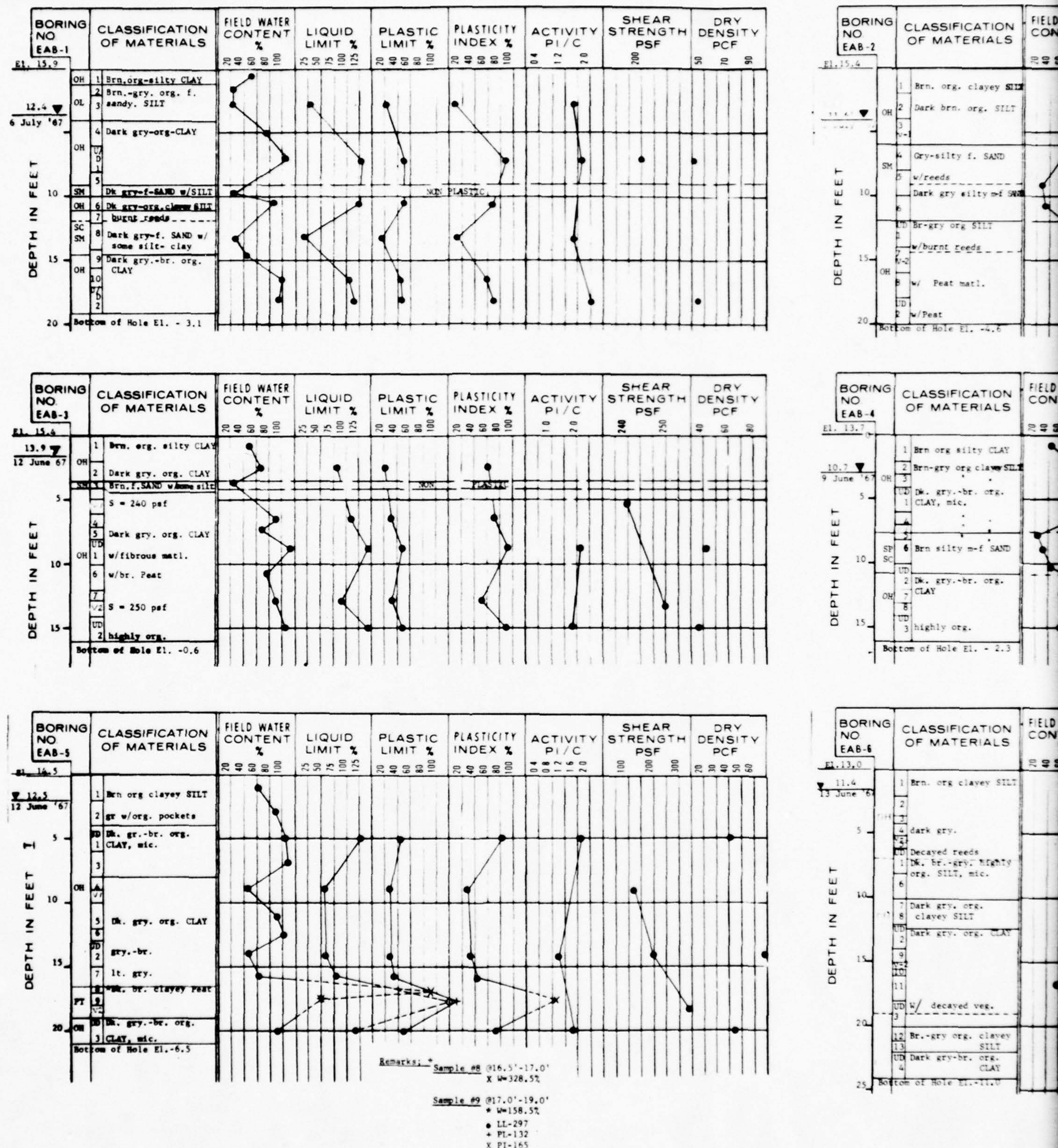


LONG RANGE SPOIL DISPOSAL STUDY

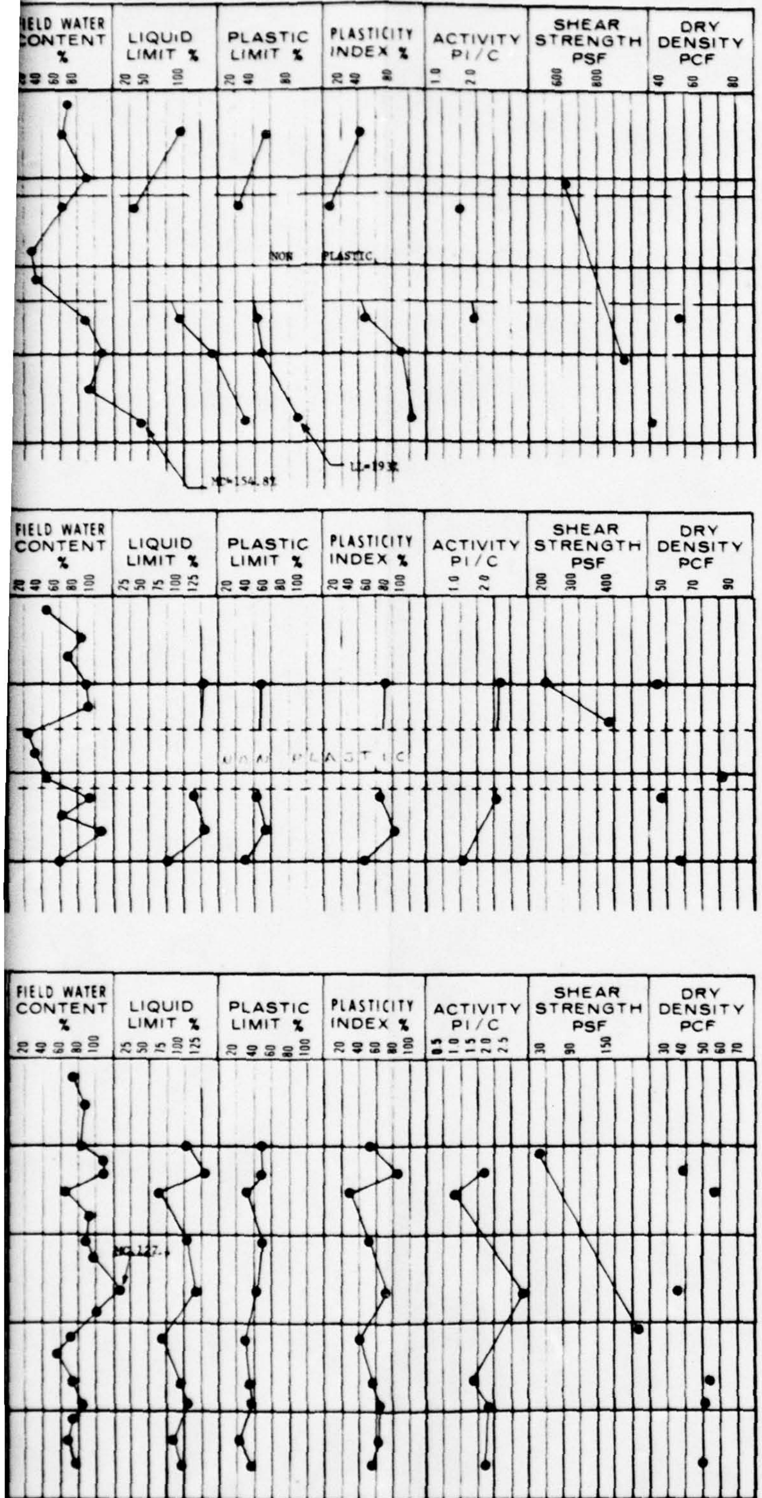
EDGEMOOR DISPOSAL AREA
LOGS OF PHYSICAL PROPERTIES

U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

2



BORINGS: EAB-1 THRU EAB-6

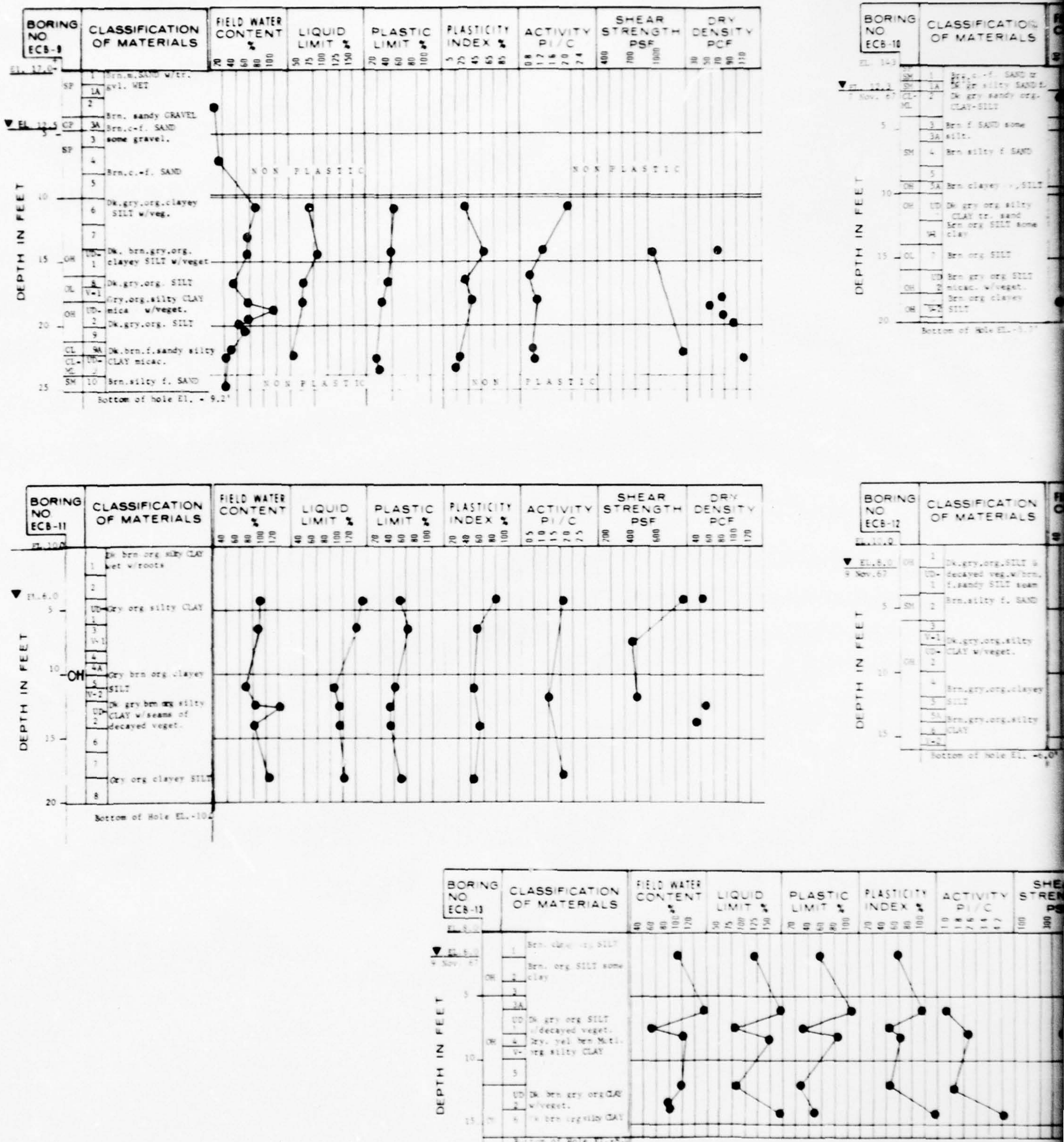


LONG RANGE SPOIL DISPOSAL STUDY

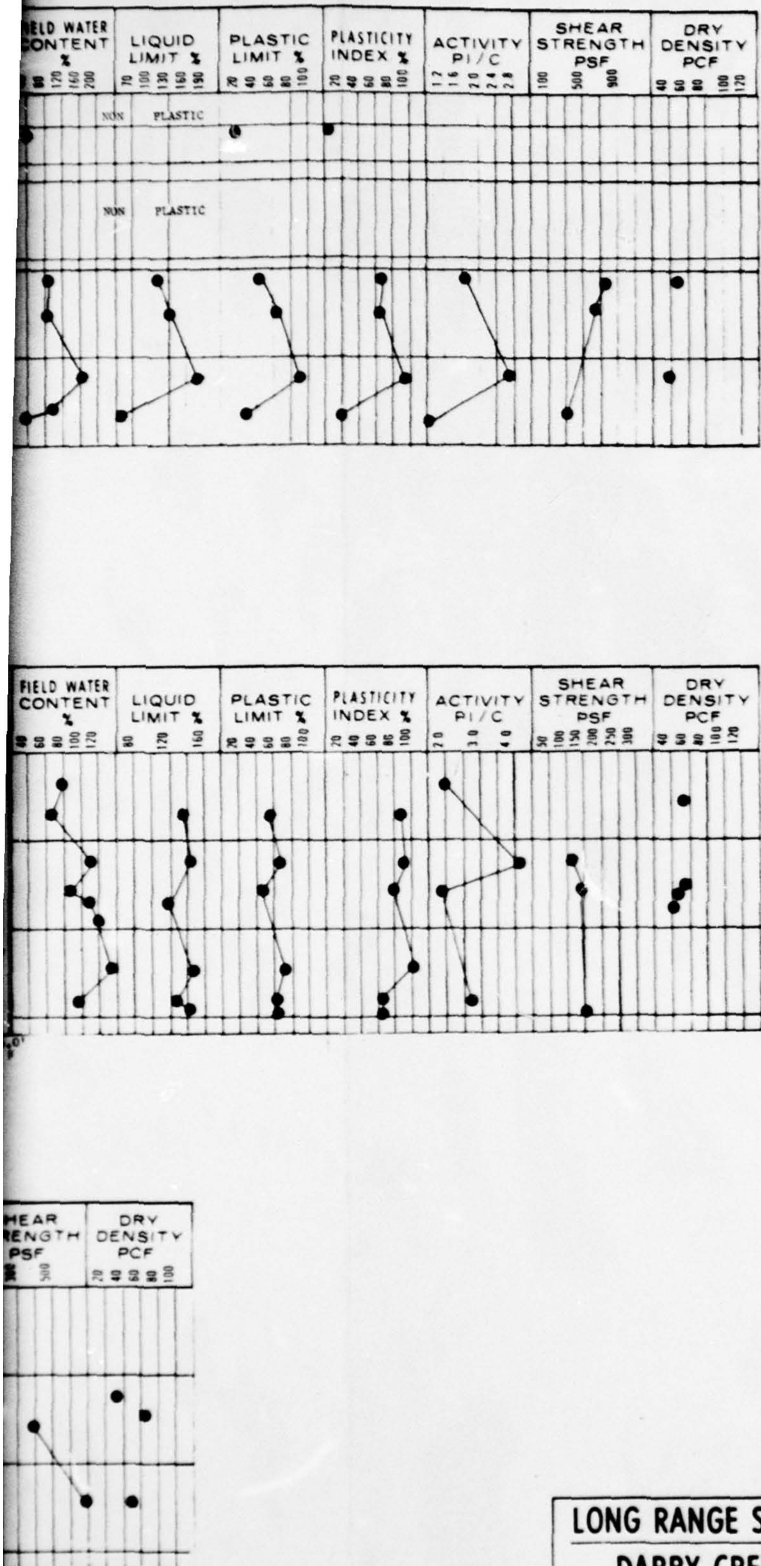
OLDMANS No.1 DISPOSAL AREA
LOGS OF PHYSICAL PROPERTIES

U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

PLATE 22



BORINGS: ECB-9 THRU ECB-13



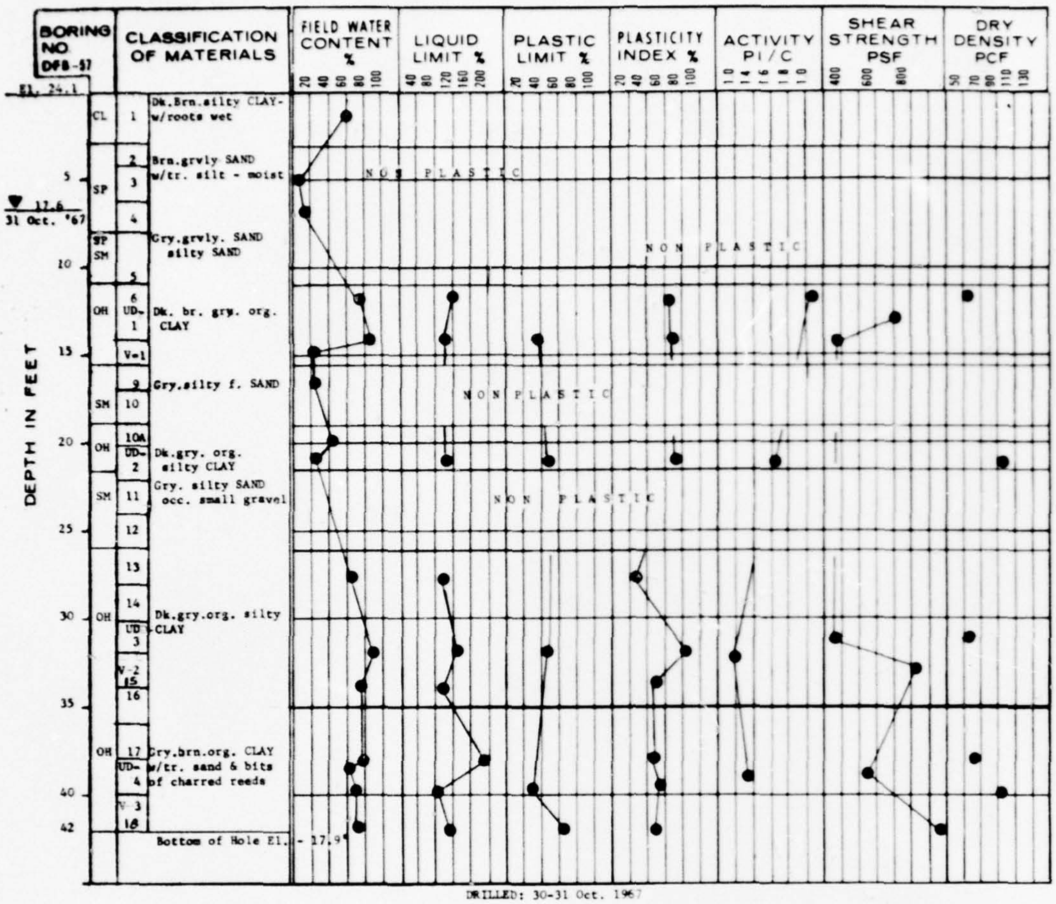
LONG RANGE SPOIL DISPOSAL STUDY

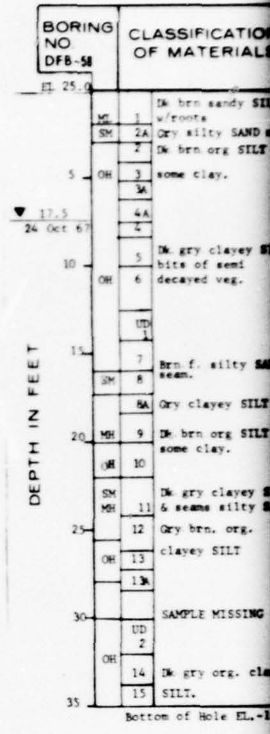
DARBY CREEK DISPOSAL AREA
LOGS OF PHYSICAL PROPERTIES

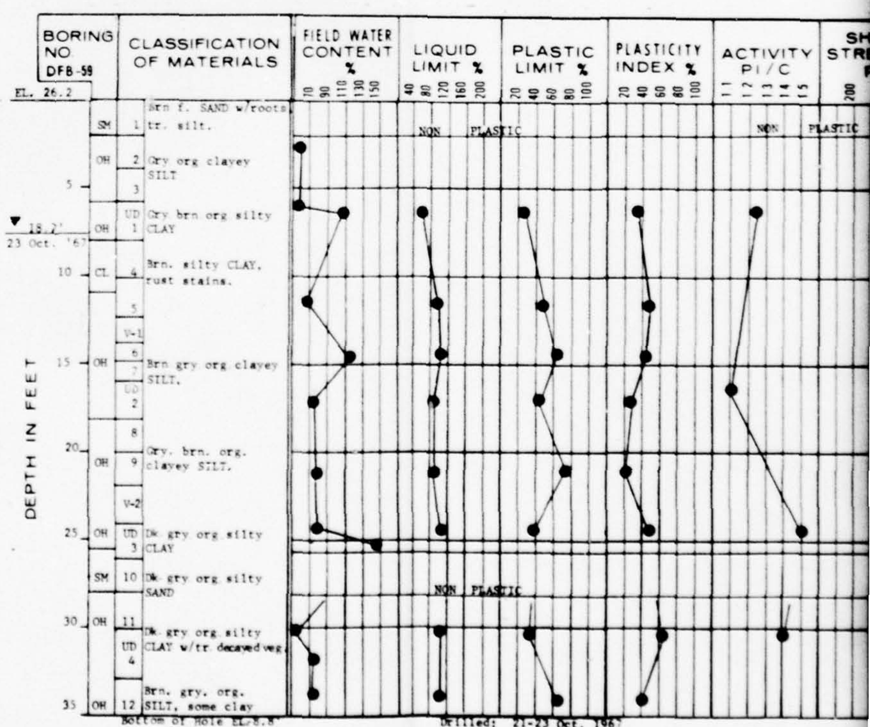
2 **U. S. ARMY ENGINEER DISTRICT**
PHILADELPHIA

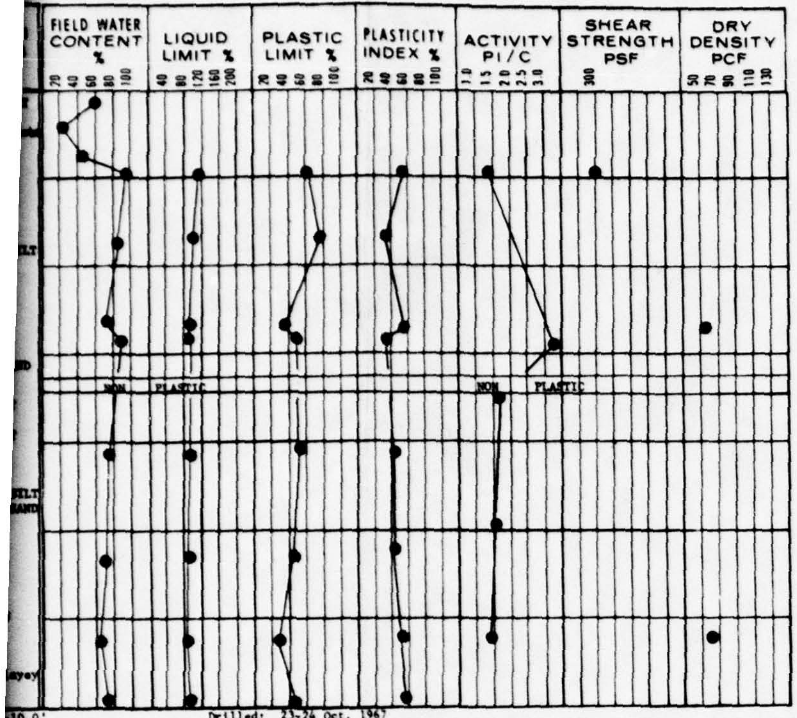
1

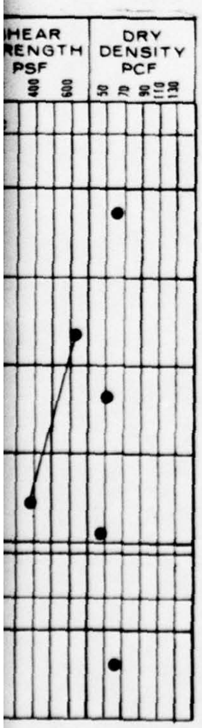
PLATE 23


BORING NO DFB-57
CLASSIFICATION OF MATERIALS
FIELD WATER CONTENT %
LIQUID LIMIT %
PLASTIC LIMIT %
PLASTICITY INDEX %
ACTIVITY PI/C
SHEAR STRENGTH PSF
DRY DENSITY PCF
EL. 24.1
DEPTH IN FEET
17.6
31 Oct. '67
CL 1 Dk.Brn.silty CLAY-w/roots wet
SP 2 3 4 Brn.grvly SAND w/tr. silt - moist
SP SM Gry.grvly. SAND silty SAND
OH 6 UD-1 Dk. br. gry. org. CLAY
V-1
9 Gry.silty f. SAND
SM 10
OH 10A UD-2 Dk.gry. org. silty CLAY
SM 11 Gry. silty SAND occ. small gravel
12
13
OH 14 UD-3 Dk.gry.org. silty CLAY
V-2
15
16
OH 17 UD-4 Gry.brn.org. CLAY w/tr. sand & bits of charred reeds
V-3
18
NON PLASTIC
Bottom of Hole El. - 17.9
DRILLED: 30-31 Oct. 1967


BORING NO DFB-58
CLASSIFICATION OF MATERIALS
EL 25.0
DEPTH IN FEET
17.5
24 Oct 67
Dk brn sandy SILT w/roots
Gry silty SAND
Dk brn org SILT some clay.
Dk gry clayey SILT bits of semi decayed veg.
Brn f. silty SAND seam.
Gry clayey SILT
Dk brn org SILT some clay.
Dk gry clayey SILT & seams silty SAND
Gry brn. org. clayey SILT
SAMPLE MISSING
Dk gry org. clay SILT.
Bottom of Hole EL.-1


BORING NO DFB-59
CLASSIFICATION OF MATERIALS
FIELD WATER CONTENT %
LIQUID LIMIT %
PLASTIC LIMIT %
PLASTICITY INDEX %
ACTIVITY PI/C
EL. 26.2
DEPTH IN FEET
18.2'
23 Oct. '67
SM 1 Brn f. SAND w/roots tr. silt.
OH 2 3 Gry org clayey SILT
OH UD 1 Gry brn org silty CLAY
CL 4 Brn. silty CLAY, rust stains.
5
V-1
OH 6 7 UD 2 Brn gry org clayey SILT.
OH 8 9 Gry. brn. org. clayey SILT.
V-2
OH UD 3 Dk gry org silty CLAY
SM 10 Dk gry org silty SAND
OH 11 UD 4 Dk gry org silty CLAY w/tr. decayed veg.
OH 12 Brn. gry. org. SILT, some clay
NON PLASTIC
Bottom of Hole EL-8.8
Drilled: 21-23 Oct. 1967





BORINGS: DFB-57,58,59

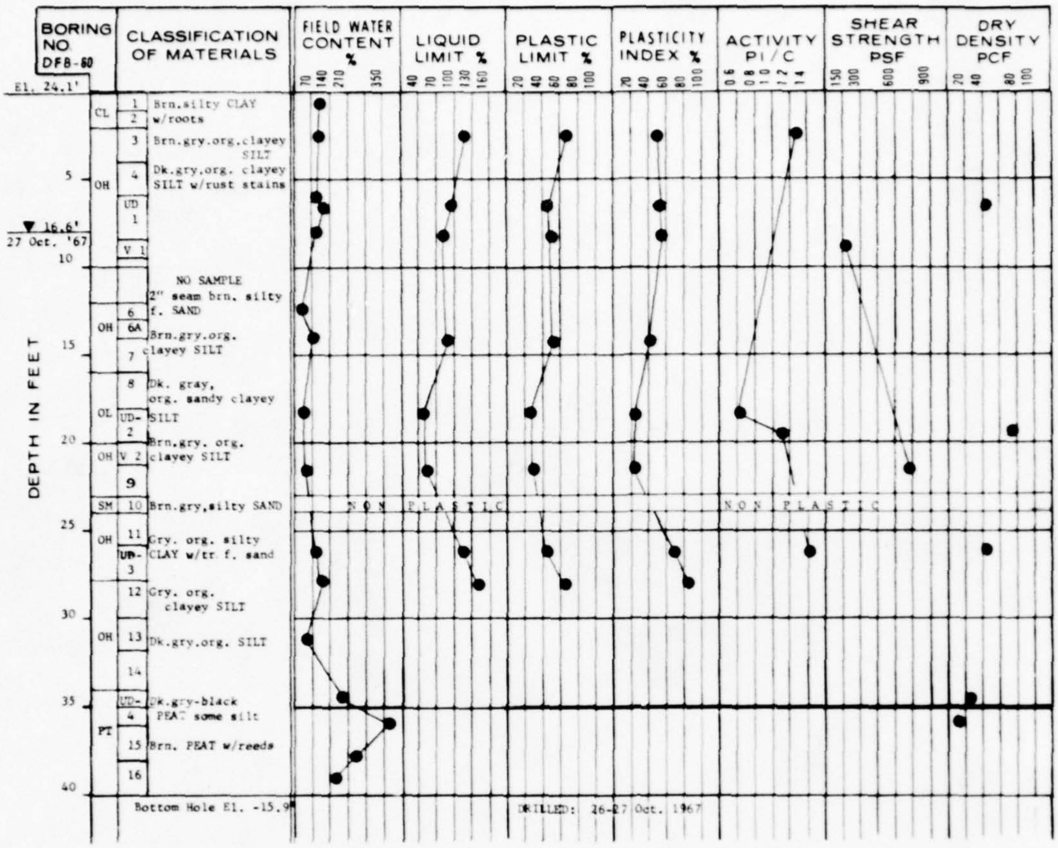
LONG RANGE SPOIL DISPOSAL STUDY

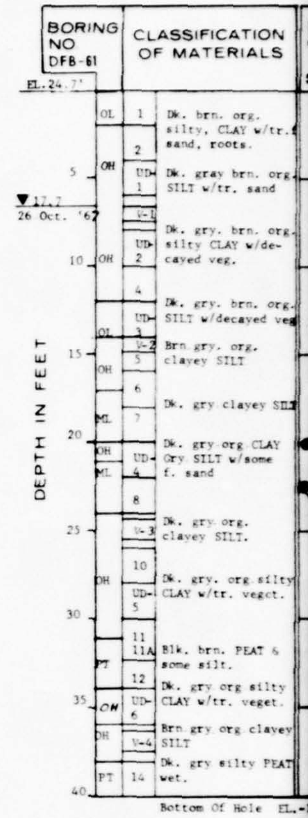
PIGEON POINT DISPOSAL AREA
LOGS OF PHYSICAL PROPERTIES

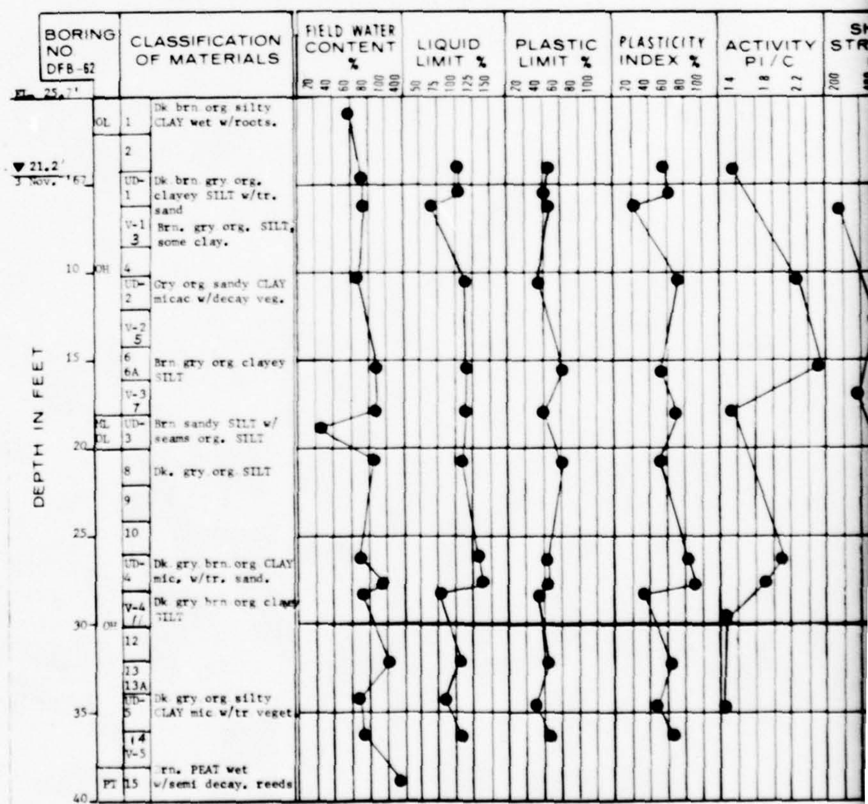
U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

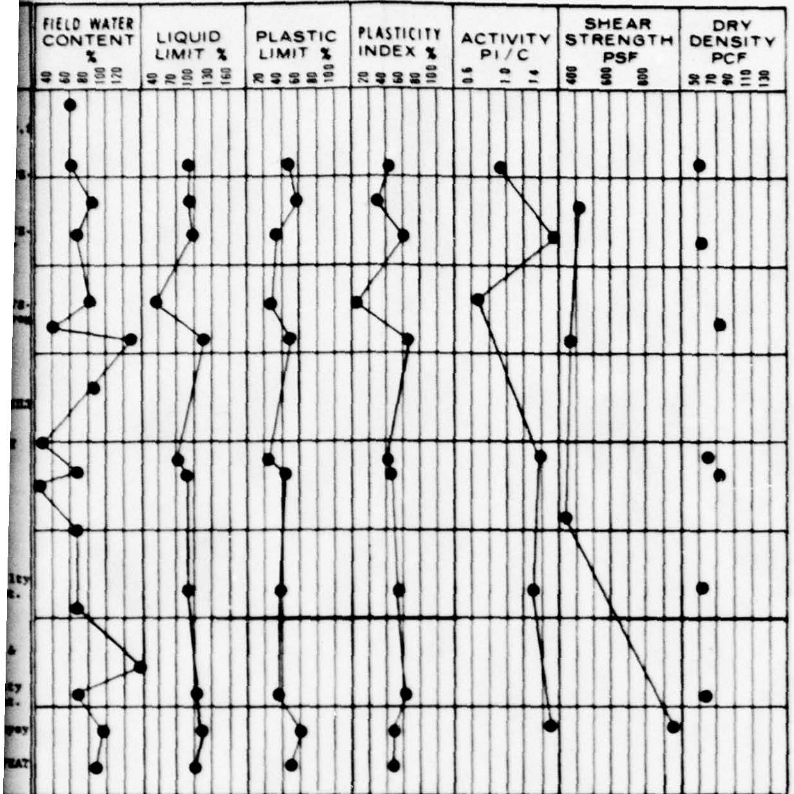
2

PLATE 24


BORING NO. DFB-60
CLASSIFICATION OF MATERIALS
FIELD WATER CONTENT %
LIQUID LIMIT %
PLASTIC LIMIT %
PLASTICITY INDEX %
ACTIVITY PI/C
SHEAR STRENGTH PSF
DRY DENSITY PCF
El. 24.1'
16.6'
27 Oct. '67
DEPTH IN FEET
Brn.silty CLAY w/roots
Brn.gry.org.clayey SILT
Dk.gry.org. clayey SILT w/rust stains
NO SAMPLE
2" seam brn. silty f. SAND
Brn.gry.org. clayey SILT
Dk. gray, org. sandy clayey SILT
Brn.gry. org. clayey SILT
Brn.gry.silty SAND
NON PLASTIC
NON PLASTIC
Gry. org. silty CLAY w/tr. f. sand
Gry. org. clayey SILT
Dk.gry.org. SILT
Dk.gry-black PEAT some silt
Brn. PEAT w/reeds
Bottom Hole El. -15.9'
DRILLED: 26-27 Oct. 1967

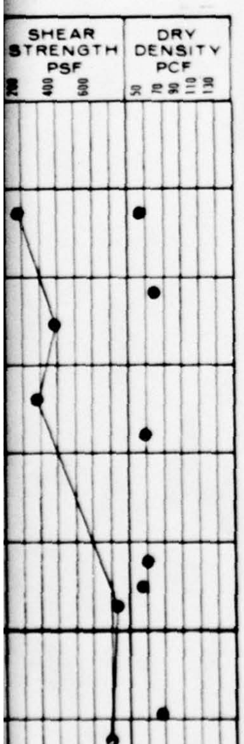

BORING NO DFB-61
CLASSIFICATION OF MATERIALS
EL. 24.7'
17.7
26 Oct. '67
DEPTH IN FEET
Dk. brn. org. silty, CLAY w/tr. sand, roots.
Dk. gray brn. org. SILT w/tr. sand
Dk. gry. brn. org. silty CLAY w/decayed veg.
Dk. gry. brn. org. SILT w/decayed veg
Brn.gry. org. clayey SILT
Dk. gry clayey SILT
Dk. gry org CLAY
Gry SILT w/some f. sand
Dk. gry org. clayey SILT.
Dk. gry. org silty CLAY w/tr. veget.
Blk. brn. PEAT & some silt.
Dk. gry org silty CLAY w/tr. veget.
Brn gry org clayey SILT
Dk. gry silty PEAT wet.
Bottom Of Hole


BORING NO DFB-62
CLASSIFICATION OF MATERIALS
FIELD WATER CONTENT %
LIQUID LIMIT %
PLASTIC LIMIT %
PLASTICITY INDEX %
ACTIVITY PI/C
EL. 25.7'
21.2'
3 Nov. '67
DEPTH IN FEET
Dk brn org silty CLAY wet w/roots.
Dk brn gry org. clayey SILT w/tr. sand
Brn. gry org. SILT, some clay.
Gry org sandy CLAY micac w/decay veg.
Brn gry org clayey SILT
Brn sandy SILT w/ seams org. SILT
Dk. gry org SILT
Dk gry brn org CLAY mic. w/tr. sand.
Dk gry brn org clayey SILT
Dk gry org silty CLAY mic w/tr veget
Brn. PEAT wet w/semi decay. reeds
Bottom of Hole EL.-14.3'
Drilled: 1-3 Nov. 1967



El. -15.3'

Drilled: 24-26 Oct. 1967



BORINGS: DFB-60,61,62

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LONG RANGE SPOIL DISPOSAL STUDY

PIGEON POINT DISPOSAL AREA
LOGS OF PHYSICAL PROPERTIES

U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

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SUMMARY SHEET - SOIL CLASSIFICATION

Delaware River Disposal Areas Long Range Study

Boring No.	Sam No.	Depth or Elev of Sample	Laboratory Classification	Mechanical Analysis: Gravel %	Sand %	Fines %	D_{10}	Atterberg Limits: LL	PL	Specific Gravity	Nat Water Cont %
EDGEMOOR DISPOSAL AREA											
EBB-1	1	0.0'-2.0'	Org SILT - OH					112	60		78.0
	3	2.5'-4.0'	Org SILT - OL					41	30		35.8
	4	6.0'-8.0'	Clayey SILT-OH					94	50		96.0
	5	8.0'-10.0'	Clayey SILT-OH								98.0
	6	10.0-11.0'	Clayey SILT-OH								101.0
	7	11.0-13.0'	Clayey SILT-OH					114	54		100.0
	8	15.0-17.0'	Clayey SILT-OH								72.0
	9	17.0-19.0'	Clayey SILT-OH					80	39		68.5
	10	20.0-21.0'	Clayey SILT-OH								81.5
	11	23.0-25.0'	Clayey SILT-OH								90.5
	12	25.0-27.0'	Silty CLAY-OH					132	45		85.5
EBB-2	1	0.0-2.0'	Sandy SILT-ML								20.5
	2	2.0-4.0'	Org SILT-OH					69	42		60.0
	3	6.0-8.0'	Clayey SILT-OH								82.5
	4	8.0-10.0'	Clayey SILT-OH					113	53		98.6
	5	12.0-14.0'	Clayey SILT-OH								76.0
	6	14.0-16.0'	Clayey SILT-OH					117	53		107.0
	7	18.0-20.0'	Clayey SILT-OH								84.0
	8	20.0-22.0'	Clayey SILT-OH								97.0
	9	24.0-26.0'	Clayey SILT-OH					138	60		116.5
	10	26.0-28.0'	Clayey SILT-OH								89.5
EBB-3	1	0.0- 2.0'	Clayey SILT-OH								80.5
	2	2.0- 4.0'	Clayey SILT-OH					130	61		110.5
	3	6.0- 8.0'	Clayey SILT-OH								131.0
	4	8.0-10.0'	Clayey SILT-OH					117	46		100.0
	5	10.0-12.0'	Clayey SILT-OH								96.5
	6	14.0-16.0'	Clayey SILT-OH					108	54		125.0
	7	16.0-17.0'	Silty GRAVEL-GM	52	23	25	0.03				16.3
	8	17.0-18.0'	Org SILT-OH		20	80		45	34		57.5
	9	20.0-22.0'	Clayey SILT-OH					105	50		93.5
	10	22.0-24.0'	Clayey SILT-OH								72.5
	11	24.0-26.0'	Org CLAY-OH					61	31		68.0
EBB-4	1	0.0- 2.0'	Clayey SILT-OH								109.0
	2	2.0- 4.0'	Clayey SILT-OH					115	49		97.0
	4	6.0- 8.0'	Clayey SILT-OH								124.0
	5	10.0-12.0'	Clayey SILT-OH					141	53		126.5
	6	12.0-14.0'	Clayey SILT-OH								139.0
	7	14.0-16.0'	Clayey SILT-OH								100.0
	8	18.0-20.0'	Silty CLAY-OH								51.2
	9	20.0-22.0'	Clayey SILT-OH					103	44		66.0
	10	22.0-24.0'	Clayey SILT-OH								114.0
	11	24.0-26.0'	Clayey SILT-OH					135	66		78.0
	12	28.0-29.0'	Clayey SILT-OH								123.0
EBB-5	1	0.0- 2.0'	Clayey SILT-OH								110.0
	2	4.0- 6.0'	Clayey SILT-OH					130	58		132.5
	3	6.0- 8.0'	Clayey SILT-OH								118.5
	4	8.0-10.0'	Clayey SILT-OH					143	60		120.0
	5	12.0-14.0'	Clayey SILT-OH								62.0
	6	14.0-16.0'	Clayey SILT-OH								85.0
	7	18.0-20.0'	Clayey SILT-OH					130	52		111.0
	8	20.0-22.0'	Clayey SILT-OH								91.6
	9	24.0-26.0'	Clayey SILT-OH					131	50		114.5
	10	26.0-28.0'	Clayey SILT-OH								106.0
	11	20.0-32.0'	Clayey SILT-OH					103	46		87.0
	12	32.0-34.0'	Clayey SILT-OH								90.5
EBB-6	1	0.0- 2.0'	Clayey SILT-OH								78.6
	2	2.0- 4.0'	Clayey SILT-OH					128	61		100.0
	3	6.0- 8.0'	Clayey SILT-OH					145	55		117.0
	4	8.0'-10.0'	Clayey SILT-OH								99.5
	5	10.0-12.0'	Clayey SILT-OH								102.5
	6	14.0-16.0'	Clayey SILT-OH					83	38		75.0
	7	16.0-18.0'	SAND-SP	2	80	18	0.04				20.6
	9	22.0-24.0'	Silty CLAY-OH					80	36		58.5
	10	25.0-27.0'	Clayey SILT-OH								79.5
	11	27.0-29.0'	Clayey SILT-OH					108	48		83.0
EBB-7	1	0.0- 2.0'	Clayey SILT-OH					116	60		82.5
	2	2.0- 4.0'	Clayey SILT-OH								100.5
	3	4.0- 5.0'	Clayey SILT-OH					131	54		116.5
	5	10.0-12.0'	Clayey SILT-OH					129	55		120.0
	6	12.0-13.0'	Clayey SILT-OH								117.0
	7	14.0-16.0'	Clayey SILT-OH								95.0
	8	20.0-20.5'	Clayey SILT-OH					130	54		97.0
	8a	20.5-21.0'	Silty CLAY-OH								42.2
	9	21.0-23.0'	Org SILT-OH		30	70		25	23		40.5
	10	25.0-27.0'	Clayey SILT-OH								80.5
	11	29.0-30.0'	Clayey SILT-OH					97	42		77.0
EBB-8	1	0.0- 2.0'	Clayey SILT-OH								70.7
	2	2.0 - 4.0'	Clayey SILT-OH					117	61		74.5
	3	6.0- 8.0'	Clayey SILT-OH								87.0
	4	8.0-10.0'	Clayey SILT-OH					122	53		107.5
	5	12.0-14.0'	Clayey SILT-OH								106.5
	6	14.0-16.0'	Clayey SILT-OH								86.2
	7	18.0-20.0'	Clayey SILT-OH					132	49		127.0
	8	20.0-22.0'	Clayey SILT-OH								106.0
	9	24.0-26.0'	Clayey SILT-OH					147	60		102.0
	10	26.0-28.0'	Clayey SILT-OH								91.2

Boring No.	Sam No.	Depth or Elev of Sample	Laboratory Classification	Mechanical Analysis: Gravel %	Sand %	Fines %	D_{10}	Atterberg Limits: LL	PL	Specific Gravity	Nat Water Cont %
EBB-9	1	0.0- 2.0'	Clayey SILT-OH								85.0
	2	2.0- 4.0'	Clayey SILT-OH					114	53		77.0
	5	10.0-12.0'	SAND-SM								32.6
	6	14.0-16.0'	Clayey SILT-OH								91.6
	7	16.0-18.0'	Clayey SILT-OH					94	40		68.5
	8	20.0-22.0'	Clayey SILT-OH								65.0
	9	22.0-24.0'	Clayey SILT-OH					71	35		57.0
EBB-10	1	0.0- 1.0'	Clayey SILT-OH								70.0
	2	1.0- 2.0'	Clayey SILT-OH								75.5
	3	2.0-4.0'	Clayey SILT-OH					109	61		70.0
	5	5.0- 6.0'	Clayey SILT-OH								63.2
	6	6.0- 7.0'	Clayey SILT-OH					109	59		93.2
	9	11.0-12.0'	Org CLAY-OH								43.8
	10	14.0-15.75	Clayey SILT-OH					78	36		54.0
	12	16.0-17.0'	Silty CLAY-OH								49.2
	13	17.0-18.0'	Clayey SAND-SC								37.0
	14	18.0-19.0'	Clayey SILT-OH					110	48		80.5
	15	19.0-20.0'	Org CLAY-OH								42.0
	16	22.0-23.0'	Sandy CLAY-OH					51	28		41.8
OLDMANS NO. 1 DISPOSAL AREA											
EAB-1	1	0.0- 1.0'	Silty CLAY-OH								54.2
	2	1.0- 2.0'	SAND-SM								26.0
	3	2.0- 4.0'	Silty SAND-SM		63	37	0.01	32	26		28.2
	4	4.0- 6.0'	Clayey SILT-OH								78.5
	5	8.0-10.0'	SAND-SM		79	21	0.06				29.8
	6	10.0-11.0'	Clayey SILT-OH					125	54		88.5
	8	12.0-14.0'	SAND-SP		85	15	0.03	24	18		29.0
	9	14.0-15.5'	Silty CLAY-OH								44.5
	10	15.5'-17.0'	Clayey SILT-OH					105	46		99.5
EAB-2	1	0.0- 2.0'	Org SILT-OH								72.1
	2	2.0- 4.0'	Clayey SILT-OH					98	55		64.5
	3	4.0- 6.0'	Clayey SILT-OH								92.0
	4	6.0- 8.0'	Silty SAND-SM		53	47	.005	30	23		63.8
	5	8.0-10.0'	SAND-SM								31.2
	6	10.0-12.0'	SAND-SM								38.2
	7	14.0-16.0'	Silty CLAY-OH					144	49		109.5
	8	16.0-18.0'	Clayey SILT-OH								98.5
EAB-3	1	0.0- 2.0'	Silty CLAY-OH								48.8
	2	2.0- 3.5'	Org CLAY-OH					88	25		71.0
	3	3.5- 4.0'	SAND-SM								29.8
	4	6.0- 7.0'	Silty CLAY-OH					114	36		105.5
	5	7.0- 8.0'	Clayey SILT-OH								76.0
	6	10.0-12.0'	Clayey SILT-OH								79.5
	7	12.0-14.0'	Silty CLAY-OH					93	35		87.0
EAB-4	1	0.0- 2.0'	Silty CLAY-OH								47.0
	2	2.0- 3.0'	Clayey SILT-OH								86.2
	3	3.0-4.0'	Clayey SILT-OH								74.0
	4	6.0- 7.0'	Clayey SILT-OH					Not adequate			94.0
	5	7.0- 7.5'	SAND-SM								27.3
	6	8.0-10.0'	SAND-SM								35.5
	7	12.0-13.0'	Clayey SILT-OH								62.0
	8	13.0-14.0'	Clayey SILT-OH					135	52		115.0
EAB-5	1	0.0- 2.0'	Clayey SILT-OH								62.2
	2	2.0- 4.0'	Clayey SILT-OH								91.6
	3	6.0- 8.0'	Clayey SILT-OH								111.5
	4	8.0-10.0'	Silty CLAY-OH					57	29		48.0
	5	10.0-12.0'	Clayey SILT-OH								95.0
	6	12.0-13.0'	Clayey SILT-OH								107.0
	7	15.0-16.5'	Silty CLAY-OH					80	36		65.5
	8	16.5-17.0'	PEAT-PT								328.5
	9	17.0-19.0'	Clayey PEAT-PT					297	132		158.5
EAB-6	1	0.0- 2.0'	Clayey SILT-OH								75.0
	2	2.0- 3.5'	Clayey SILT-OH								92.5
	4	4.0- 5.0'	Clayey SILT-OH					103	48		82.0
	5	5.5- 6.0'	Clayey SILT-OH								110.5
	6	8.0-10.0'	Clayey SILT-OH								97.5
	7	10.0-11.0'	Clayey SILT-OH					103	48		91.0
	8	11.0-12.0'	Clayey SILT-OH								101.5
	9	14.0-15.0'	Clayey SILT-OH								100.0
	10	15.0-16.0'	Silty CLAY-OH					76	33		72.0
	11	16.0-18.0'	Clayey SILT-OH								57.0
	12	20.0-21.0'	Clayey SILT-OH								79.5
	13	21.0-22.0'	Org CLAY-OH					92	26		71.0
DARBY CREEK DISPOSAL AREA											
ECB-9	1	0.0-1.4'	SAND-SP								
	1a	1.4-2.0'	SAND-SP								
	2	2.8-4.0'	SAND-SP								8.8
	3a	4.0-4.4'	Sandy GRAVEL-GP								
	3	4.4- 6.0'	SAND-SP								
	4	6.0- 8.0'	SAND-SP								12.0
	5	8.0-10.0'	SAND-SP								
	6	10.0-12.0'	Clayey SILT-OH		10	90		68	45		69.5
	7	12.0-14.0'	Org SILT-OH								58.5
	8	16.0-17.0'	Silty CLAY-OH			100		58	36	2.50	38.5
	9	20.0-21.6'	Org SILT-OH								53.0
	9a	21.6-22.0'	Sandy CLAY-CL								30.8
	10	24.0-25.0'	Silty SAND-SM								23.2

Boring No.	Sam No.	Depth or Elev of Sample	Laboratory Classification
ECB-10	1	0.0- 1.5'	SAND-SP
	1a	1.5- 2.0'	Silty S
	2	2.0- 4.0'	Sandy C
	3	4.0- 5.0'	SAND-SM
	3a	5.0- 6.0'	SAND-SM
	4	6.0- 8.0'	Silty S
	5	8.0- 9.8'	Silty S
	5a	9.8-10.0'	Org SIL
	6	12.0-14.0'	Org SIL
	7	14.0-16.0'	Org SIL
	8	18.0-20.0'	Org SIL
ECB-11	1	0.0- 2.0'	Org SIL
	2	2.0- 4.0'	Sandy S
	3	6.0- 8.0'	Org SIL
	4	8.0- 9.8'	Org SIL
	4a	9.8-10.0'	Org SIL
	5	10.0-12.0'	Org SIL
	6	14.0-16.0'	Org SIL
	7	16.0-18.0'	Org SIL
	8	18.0-20.0'	Org SIL
ECB-12	1	0.0- 2.0'	Org SIL
	2	4.0- 6.0'	Silty S
	3	6.0- 8.0'	Clayey
	4	10.0-12.0'	Org SIL
	5	12.0-13.0'	Org SIL
	5a	13.0-14.0'	Org SIL
	6	14.0-16.0'	Org SIL
ECB-13	1	0.0- 2.0'	Org SIL
	2	2.0- 4.0'	Org SIL
	3	4.0- 5.0'	Org CLA
	3a	5.0- 6.0'	Org SIL
	4	8.0-10.0'	Org SIL
	5	10.0-12.0'	Org SIL
	6	14.0-16.0'	Silty C
PIGEON POINT DISPOSAL AREA			
DFB-57	1	0.0- 2.0'	Clayey
	2	2.0- 4.0'	SAND-SP
	3	4.0- 6.0'	SAND-SP
	4	6.0- 8.0'	Sandy
	5	8.0-10.0'	Sandy
	6	10.8-12.0'	Clayey
	7	14.0-14.6'	Clayey
	8	14.6-15.9'	SILT-M
	9	17.0-18.0'	Sandy
	10	18.0-19.3'	Silty
	10a	19.3-20.0'	Clayey
	11	22.0-24.0'	Silty
	12	24.0-26.0'	Silty
	13	26.0-28.0'	SILT-
	14	28.0-30.0'	Clayey
	15	32.0-34.0'	Clayey
	16	34.0-36.0'	Clayey
	17	36.0-38.0'	Clayey
	18	40.0'-42.0'	Clayey
DFB-58	1	0.0- 2.0'	Org SI
	2a	2.0- 3.0'	Silty
	2	3.0- 4.0'	Clayey
	3	4.0- 5.0'	Clayey
	3a	5.0- 6.0'	Org SI
	4a	6.0- 7.4'	Sandy
	4	7.4- 8.0'	Clayey
	5	8.6-10.0'	Org S
	6	10.0-12.0'	Org S
	7	14.0-16.0'	Clayey
	8	16.6-17.2'	Silty
	8a	17.2-18.0'	Clayey
	9	18.0-20.0'	Clayey
	10	20.6-21.6'	Clayey
	11	23.0-24.0'	Silty
	12	24.4-25.4'	Silty
	13	26.6-27.2'	Clayey
	13a	27.2-28.0'	Clayey
	14	32.0 - 34.0'	Clayey
	15	34.0-35.0'	Clayey
DFB-59	1	1.4- 2.0'	Org
	2	2.0- 4.0'	Org
	3	4.0- 6.0'	Org
	4	8.6-10.0'	Org
	5	11.2-12.0'	Org
	6	12.0-14.0'	Org
	7	14.0-15.4'	Org
	8	18.0-20.0'	Org
	9	20.0-22.0'	Org
	9a	22.0-24.0'	Clay
	10	26.0-28.0'	SILT
	11	28.0-29.5'	Org
	11a	29.6-30.0'	Clay
	12	33.0'35.0'	Org

LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT WATER CONT %
AND-SP-SM								
ilty SAND-SM								22.1
ndy CLAY-SILT(CL-ML)					27	20		41.0
AND-SM								
AND-SM								
ilty SAND-SM								26.0
ilty SAND-SM								33.2
rg SILT-OHm								87.5
rg SILT-OH					131	67	2.45	105.0
rg SILT-OL								43.7
rg SILT-OL		1	99		52	32	2.47	39.0
rg SILT-OH								91.0
andy SILT-OL								49.2
rg SILT-OH		2	98		122	65	2.45	92.5
rg SILT-OH								103.0
rg SILT-OH								52.0
rg SILT-OH					89	41		71.6
rg SILT-OL								41.5
rg SILT-OH								64.5
rg SILT-OH		1	99		103	56	2.67	107.0
rg SILT-OH								84.3
ilty SAND-SM								31.5
layey SILT-OH			100		152	63	2.48	110.0
rg SILT-OH								84.2
Org SILT-OH					168	68		133.0
Org SILT-OH								101.0
Org SILT-OH			100		123	60	2.50	94.2
Org SILT-OH								94.0
Org SILT-OH					120	60		93.5
Org CLAY-OH								106.5
Org SILT-OH								101.5
Org SILT-OH					150	84		104.0
Org SILT-OH								123.0
Silty CLAY-OH		3	97		172	52	2.50	82.6
REA								
Clayey SILT-OH								59.8
SAND-SP								
SAND-SP								7.2
Sandy GRAVEL-GP+GM								12.7
Sandy GRAVEL-GP								
Clayey SILT-OH			100		120	57	2.48	77.8
Clayey SILT-OH								97.3
SILT-ML								
Sandy SILT-ML								30.2
Silty SAND-SM								25.9
Clayey SILT-OH								83.9
Silty SAND-SM								25.9
Silty SAND-SM								22.3
SILT-OH					72	45	2.44	63.5
Clayey SILT-OH								80.3
Clayey SILT-OH			100		102	50	2.45	73.9
Clayey SILT-OH								62.0
Clayey SILT-OH					193	43		78.3
Clayey SILT-OH					117	65	2.44	76.7
Org SILT-OH								59.8
Silty SAND-OH								25.6
Clayey SILT-OH								101.9
Clayey SILT-OH					116	61	2.44	97.5
Org SILT-OH								50.2
Sandy SILT-OL								45.7
Clayey SILT-OH								59.3
Org SILT-OH					110	75	2.42	84.0
Org SILT-OH								72.3
Clayey SILT-OH			100		89	51		89.0
Silty SAND-SM								33.1
Clayey SILT-OH								77.7
Clayey SILT-OH								80.9
Clayey SILT-OH			100		98	56	2.44	75.8
Silty SAND-SM								29.8
Silty SAND-SM								29.5
Clayey SILT-OH					88	45		70.2
Clayey SILT-OH								75.6
Clayey SILT-OH								87.2
Clayey SILT-OH					99	42	2.49	77.5
Org SILT-OH								56.8
Org SILT-OH					72	43		61.0
Org SILT-OH								61.8
Org SILT-OH								63.3
Org SILT-OH					98	49		69.4
Org SILT-OH								73.0
Org SILT-OH			100		107	65	2.49	66.1
Org SILT-OH								78.0
Org SILT-OH					95	75		79.3
Clayey SILT-OH								64.4
SILT-OL								45.8
Org SILT-OH								52.8
Clayey SILT-OH								73.9
Org SILT-OH					103	63	2.44	73.3

BORING NO.	SAM NO	DEPTH OR ELEV OF SAMPLE	LABORATORY CLASSIFICATION	MECHANICAL ANALYSIS GRAVEL %	SAND %	FINES %	D_{10}	ATTERBERG LIMITS LL	PL	SPECIFIC GRAVITY G	NAT WATER CONT %
DFB-60	1	0.0- 1.0'	Org SILT-OH								102.8
	2	1.0- 2.0'	Org SILT-OH								102.8
	3	2.0- 4.0'	Org SILT-OH					117	64		97.0
	4	4.0- 6.0'	Org SILT-OH								80.8
	5	8.0-10.0'	Org SILT-OH			100		108	53	2.49	92.2
	6	12.0-13.4'	Sandy SILT-OL								47.3
	6a	13.8-14.0'	SAND-SM								32.9
	7	14.0-16.0'	Org SILT-OH					90	50		78.4
	8	16.0-18.0'	Org SILT-OH								55.3
	9	20.0-22.0'	Org SILT-OL			100		53	30	2.49	46.7
	10a	23.0-23.5'	Silty SAND-SM								23.9
	10	23.5-24.0'	SILT-ML								29.8
	11	24.0-26.0'	Org SILT-OH								71.4
	12	28.0-30.0'	Clayey SILT-OH					147	62	2.48	105.1
	13	30.0-31.8'	Org SILT-OH								91.7
	14	32.0-34.0'	Clayey SILT-OH								59.7
	15	36.0-38.0'	PEAT-PT								232.5
	16	38.0-40.0'	PEAT-PT								158.2
DFB-61	1	0.0- 2.0'	SILT-OH								60.1
	2	2.0- 4.0'	Org SILT-OH								59.8
	3	6.0- 8.0'	Org SILT-OH		7	93		96	60	2.56	83.8
	4	11.0-12.0'	Org SILT-OH								90.5
	5	14.0-16.0'	Org SILT-OH					121	54	2.49	115.1
	6	16.0-18.0'	Org SILT-OH								82.0
	7	19.0-20.0'	Org SILT-OL								39.1
	8	23.2-24.0'	Org SILT-OH					96	47	2.47	68.7
	9	24.0-26.0'	Sandy SILT-OL								42.7
	10	26.0-28.2'	Org SILT-OH								72.1
	11	30.2-31.4'	Org SILT-OL								45.3
	11a	31.4-32.2'	PEAT-PT								82.3
	12	32.2-34.2'	SILT-OH								241.7
	13	36.2-38.0'	Org SILT-OH		2	98		113	61	2.47	99.4
	14	38.0-40.0'	Org SILT-OH					101	53		89.8
DFB-62	1	0.0- 2.0'	Org SILT-OH								53.3
	2	2.0- 4.0'	Org SILT-OH								96.0
	3	6.0- 8.0'	Org SILT-OH					72	47	2.44	75.1
	4	8.0-10.0'	Clayey SILT-OH								77.8
	5	12.0-14.0'	Clayey SILT-OH								81.7
	6	14.0-15.0'	SILT-OH								59.3
	6a	15.0-16.0'	Clayey SILT-OH			100		120	63	2.48	92.3
	7	16.0-18.0'	Org SILT-OH								93.2
	8	20.0-22.0'	Clayey SILT-OH					118	62	2.43	87.7
	9	22.0-24.0'	Clayey SILT-OH								102.3
	10	24.0-26.0'	Org SILT-OH								62.3
	11	28.0-30.0'	Org SILT-OH			100		77	39	2.49	76.2
	12	30.0-32.0'	Org SILT-OH								75.3
	13	32.0-33.3'	Org SILT-OH					105	43		81.6
	13a	33.6-34.0'	Org SILT-OH								78.4
	14	36.0-38.0'	Org SILT-OH		2	98		112	50	2.50	81.4
	15	38.0-40.0'	PEAT-PT								396.4

LONG RANGE SPOIL DISPOSAL STUDY

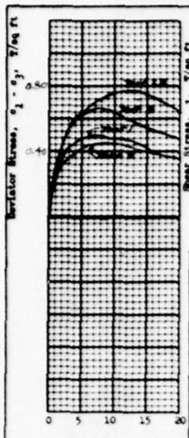
SUMMARY OF
CLASSIFICATION TEST DATA

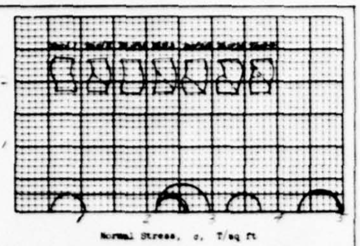
2 U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

SUMMARY OF DETAILED LABORATORY TESTS

Boring	Sample	Depth	Classification	Atterberg Limits LL	PL	PI	Mechanical Analysis Gr	Sand	Fines	d (pcf)	W_o (%)	S_o (%)	Shear Test Type	ø	C (tsf)	Consolidation Test e_o	G_s	C_c
I. EDGEMOOR DISPOSAL AREA:																		
EBB-1	UD-2	13-15	Org CLAY - CL	121	42	79	0	3	97	41	109.4	98				2.654	2.56	1.13
2	UD-2	16-18	Org CLAY - OH	119	49	70	0	0	100	48	86.5	92	Q	0	0.28			
										45	88.8	90	R	12.4	0.15			
													$\bar{R}$	31.0	0			
2	UD-3	22-24	Org CLAY - OH	104	46	58	0	0	100	46	93.6	99						
3	UD-2	12-14	Org CLAY - OH	120	43	77	0	0	100	42	101.0	92						
4	UD-1	8-10	Org CLAY - OH	109	43	66	0	0	100	43	103.9	98						
5	UD-1	2- 4	Org CLAY - OH	134	51	83	0	0	100	33	147.4	99						
										38	110.8	89	Q	0	0.15			
										40	100.5	89	R	14.7	0.05			
													$\bar{R}$	30.8	0			
5	UD-3	16-18	Org CLAY - OH	122	45	77	0	0	100	43	108.5	99				2.643	2.49	0.90
5	UD-4	22-24	Org CLAY - OH	121	49	72	0	0	100	45	93.2	93	Q	0	0.25			
										43	99.7	94	R	13.8	0.20			
													$\bar{R}$	35.9	0			
5	UD-6	34-36	Org CLAY - OH	124	44	80	0	0	100	44	101.4	100				2.482	2.46	1.02
6	UD-1	4- 6	Org CLAY - OH	110	41	69	0	0	100	43	98.6	95	Q	0	0.12			
										44	93.8	93	R	14.5	0.05			
													$\bar{R}$	33.8	0			
6	UD-3	21-23	Org CLAY - OH	87	38	49	0	0	100	57	62.2	91	Q	2.5	0.25			
										52	73.9	91	R	14.5	0.13			
													$\bar{R}$	29.8	0			
6	UD-4	29-31	Org SILT - OH	164	74	94	0	0	100	34	132.7	96				3.141	2.26	1.43
7	UD-2	17-19	Org CLAY - OH	130	45	85	0	0	100	40	111.5	96				2.918	2.50	1.00
7	UD-4	27-29	Org CLAY - OH	56	36	20	0	0	100	57	63.6	96				1.544	2.34	0.51
8	UD-2	10-12	Org CLAY - OH	107	45	62	0	0	100	46	88.1	90				2.489	2.55	0.87
8	UD-3	16-18	Org SILT - OH	51	32	19	0	3	97	72	44.2	89	Q	0	0.25			
										70	46.7	92	R	13.2	0.25			
													$\bar{R}$	37.2	0			
9	UD-2	12-14	Org SILT - OH	89	49	40	0	4	96	48	84.0	91	Q	0	0.30			
										51	77.0	93	R	15.4	0.15			
													$\bar{R}$	38.7	0			
										59	65.9	100				1.681	2.54	0.48
9	UD-3	18-20	Org CLAY - OH	96	38	58	0	0	100	58	65.8	97				1.737	2.55	0.50
II. OLDMANS NO. 1 DISPOSAL AREA:																		
EAB-1	UD-1	6- 8	Org CLAY - OH	134	49	85	0	0	100	41	108.6	98				2.771	2.49	1.28
										41	108.2	95	Q	0	0.15			
										41	98.5	91	R	12.4	0.10			
													$\bar{R}$	29.7	0			
2	UD-1	12-14	Org CLAY - OH	92	43	49	0	0	100	48	93.0	100				2.218	2.47	0.95
2	UD-2	18-20	Org CLAY - OH	193	90	103	0	0	100	31	154.8	98				3.532	2.23	1.80
3	UD-1	8-10	Org CLAY - OH	149	52	97	0	0	100	40	114.7	98				2.877	2.46	0.90
4	UD-1	4- 6	Org CLAY - OH	127	51	76	0	6	94	41	103.3	91	Q	0	0.15			
										45	88.9	90	R	14.2	0.10			
													$\bar{R}$	31.4	0			
5	UD-2	13-15	Org CLAY - OH	63	30	33	0	0	100	71	44.2	88	Q	0	0.35			
										71	42.2	87	R	15.9	0.10			
													$\bar{R}$	32.3	0			
6	UD-2	12-14	Org CLAY - OH	115	42	73	0	2	98	37	127.2	99				3.254	2.54	1.16
III. DARBY CREEK DISPOSAL AREA:																		
ECB-9	UD-1	14-16	Org SILT - OH	83	37	46	0	2	98	62	53.5	88	Q	1.7	0.45			
9	UD-3	22-24	Sandy CLAY - CL	24	20	4	0	45	55	102	23.8	100				0.626	2.65	0.12
										100	24.3	97	Q	0	0.60			
10	UD-1	10-11.5	Org CLAY - OH	114	45	69	0	5	95	45	92.5	91	Q	0	0.39			
10	UD-2	16-18	Org SILT - OH	184	91	93	0	0	100	34	139.3	99				3.230	2.29	1.34
11	UD-1	4- 6	Org CLAY - OH	135	54	81	0	4	96	42	91.8	85	Q	1.6	0.42			
										41	95.0	85	R	14.8	0.20			
													$\bar{R}$	35.8	0			
11	UD-2	12-14	Org CLAY - OH	98	38	60	0	0	100	50	83.3	97				2.202	2.56	0.61
12	UD-2	8-10	Org CLAY - OH	120	43	77	0	0	100	42	103.2	92	R	14.3	0.07			
													$\bar{R}$	38.5	0			
13	UD-1	7- 8	Org CLAY - OH	79	34	45	0	0	100	65	55.5	100				1.400	2.51	0.39
13	UD-2	12-14	Org CLAY - OH	79	31	47	0	0	100	52	77.5	99	R	10.8	0.35			
													$\bar{R}$	34.0	0			
IV. PIGEON POINT DISPOSAL AREA:																		
DFB-57	UD-1	12-14	Org CLAY - OH	103	37	66	0	12	88	51	80.6	96	Q	0	0.35			
57	UD-3	30-32	Org CLAY - OH	101	38	63	0	0	100	53	75.1	93	Q	3.7	0.18			
57	UD-4	38-40	Org CLAY - OH	91	34	57	0	0	100	62	60.3	100				1.522	2.52	0.52
										56	65.2	100	Q	0	0.28			
58	UD-1	12-14	Org CLAY - OH	93	38	55	0	5	95	56	72.8	100				1.860	2.55	0.75
59	UD-1	6- 8	Org CLAY - OH	63	28	35	0	15	85	45	56.0	97	R	13.7	0.15			
													$\bar{R}$	38.3	0			
60	UD-1	6- 8	Org SILT - OH	99	46	53	0	0	100	50	79.0	94				2.195	2.57	0.96
60	UD-2	18-20	Org Sandy	52	27	25	0	16	84	75	41.3	90	Q	0	0.35			
			CLAY - OH							79	38.2	92	R	13.4	0.23			
													$\bar{R}$	35.0	0			
60	UD-3	26-28	Org CLAY - OH	118	46	72	0	0	100	46	96.0	99				2.439	2.52	0.98
61	UD-1	4- 5	Org SILT - OH	91	49	42	0	0	100	54	56.6	79	Q	3.3	1.15			
61	UD-2	8-10	Org CLAY - OH	100	39	61	0	10	90	55	62.3	86	Q	5.8	0.55			
61	UD-3	12-14	Org SILT - OL	40	32	8	0	7	93	73	44.0	96	R	15.1	0.25			
													$\bar{R}$	35.4	0			
61	UD-4	21-22	Org CLAY - OH	70	29	41	0	0	100	61	63.6	99				1.631	2.55	0.50
61	UD-6	34-36	Org CLAY - OH	101	39	62	0	0	100	55	72.4	99				1.858	2.54	0.77
62	UD-3	19-20	Org CLAY - OH	116	42	74	0	0	100	50	85.7	99				2.185	2.53	0.77
62	UD-4	26-28	Org CLAY - OH	136	43	93	0	0	100	42	105.4	97	Q	0	0.18			
62	UD-5	34-36	Org CLAY - OH	85	36	49	0	0	100	67	53.8	100				1.378	2.57	0.43

NOTE: For the shear tests the values shown for d, W_o and S_o are the average of the set of specimens used.





Shear Strength Parameters

ϕ = — °

tan ϕ = —

c = 0.28 T/sq ft

Method of saturation: None

☐ Controlled stress
☒ Controlled strain

Test No.			1	2	2B	3
Initial	Water content	w_o	91.4 %	91.2 %	73.3 %	85.5 %
	Void ratio	e_o	2.489	2.482	2.074	2.284
	Saturation	S_o	93.6 %	93.7 %	90.1 %	93.3 %
	Dry density, lb/cu ft	γ_d	45.6	45.7	51.8	48.5
Before Shear	Water content	w_c	— %	— %	— %	— %
	Void ratio	e_c	—	—	—	—
	Saturation	S_c	— %	— %	— %	— %
	Final back pressure, T/sq ft	u_o	—	—	—	—
Final	Water content	w_f	— %	— %	— %	— %
	Void ratio	e_f	—	—	—	—
Minor principal stress, T/sq ft		σ_3	0.54	2.16	2.16	4.32
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.50	0.45	0.77	0.66
Time to failure, min		t_f	6.8	8.0	13.8	6.8
Rate of strain, percent/min			1.03	1.03	0.97	1.03
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.41*	0.40*	0.75*	0.55*
Initial diameter, in.		D_o	1.40	1.40	1.40	1.40
Initial height, in.		H_o	3.15	3.15	3.35	3.15

Type of test: Q | Type of specimen: Undisturbed

Classification: Organic CLAY (OH)

LL 119 | PL 49 | PI 70 | D_{10} < 0.001 | G_s 2.55

Remarks: * Stress at 15% Strain

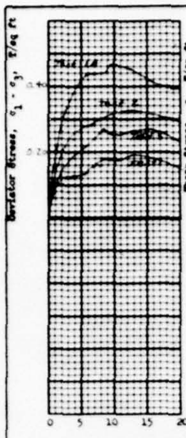
Project: Long Range Delaware River Disposal Area

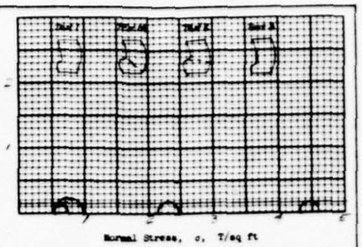
Area: Edgemoor

Boring No. EBB-2 | Sample No. UD2

Depth: 16.0'-18.0' | Date: Sept 1967

TRIAXIAL COMPRESSION TEST REPORT





Shear Strength Parameters

ϕ = — °

tan ϕ = —

c = 0.15 T/sq ft

Method of saturation: None

☐ Controlled stress
☒ Controlled strain

Test No.			1	1A	2	3
Initial	Water content	w_o	124.2 %	100.1 %	108.6 %	110.3 %
	Void ratio	e_o	3.610	2.914	3.014	2.977
	Saturation	S_o	85.3 %	87.3 %	89.3 %	94.6 %
	Dry density, lb/cu ft	γ_d	33.6	39.5	38.6	38.9
Before Shear	Water content	w_c	— %	— %	— %	— %
	Void ratio	e_c	—	—	—	—
	Saturation	S_c	— %	— %	— %	— %
	Final back pressure, T/sq ft	u_o	—	—	—	—
Final	Water content	w_f	— %	— %	— %	— %
	Void ratio	e_f	—	—	—	—
Minor principal stress, T/sq ft		σ_3	0.54	0.54	2.16	4.32
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.18	0.44	0.33	0.27
Time to failure, min		t_f	8.0	5.5	5.5	8.0
Rate of strain, percent/min			1.03	1.02	1.02	1.03
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.17	0.42*	0.32*	0.25
Initial diameter, in.		D_o	1.40	1.40	1.40	1.40
Initial height, in.		H_o	3.15	3.17	3.17	3.15

Type of test: Q | Type of specimen: Undisturbed

Classification: Organic CLAY (OH)

LL 134 | PL 57 | PI 83 | D_{10} < 0.001 | G_s 2.48

Remarks: * Stress at 15% Strain

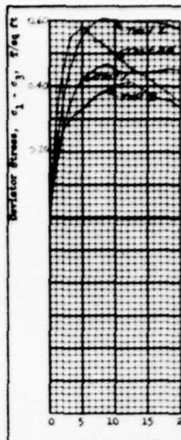
Project: Long Range Delaware River Disposal Area

Area: Edgemoor

Boring No. EBB-5 | Sample No. UD1

Depth: 2.0' - 4.0' | Date: Sept 1967

TRIAXIAL COMPRESSION TEST REPORT



Shear Strength Parameters

ϕ = — °

tan ϕ = —

c = 0.25 T/sq ft

Method of saturation: None

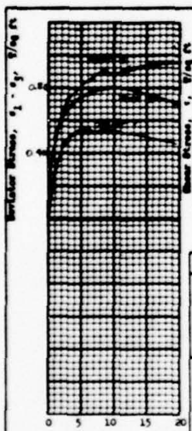
☐ Controlled stress
☒ Controlled strain

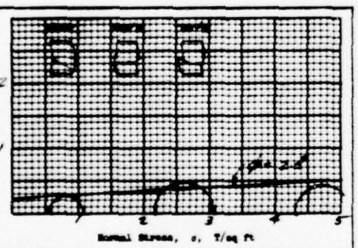
Type of test: Q | Type of specimen: Un…

Classification: Organic CLAY (OH…

LL 121 | PL 49 | PI 7…

Remarks: * Stress at 15% strain





Shear Strength Parameters

ϕ = 2.5 °

tan ϕ = 0.044

c = 0.25 T/sq ft

Method of saturation: None

☐ Controlled stress
☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	64.3 %	61.8 %	60.4 %	%
	Void ratio	e_o	1.827	1.679	1.633	
	Saturation	S_o	88.0 %	92.0 %	92.5 %	%
	Dry density, lb/cu ft	γ_d	55.2	58.6	59.2	
Before Shear	Water content	w_c	— %	— %	— %	%
	Void ratio	e_c	—	—	—	
	Saturation	S_c	— %	— %	— %	%
	Final back pressure, T/sq ft	u_o	—	—	—	
Final	Water content	w_f	— %	— %	— %	%
	Void ratio	e_f	—	—	—	
Minor principal stress, T/sq ft		σ_3	0.54	2.16	4.32	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.55	0.90	0.80	
Time to failure, min		t_f	4.9	8.0	9.2	
Rate of strain, percent/min			1.03	1.01	1.03	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.50*	0.94*	[illegible]	
Initial diameter, in.		D_o	1.40	1.40	1.40	
Initial height, in.		H_o	3.15	3.23	3.15	

Type of test: Q | Type of specimen: Undisturbed

Classification: Organic CLAY (OH)

LL [illegible] | PL [illegible] | PI 49 | D_{10} < 0.001 | G_s 2.50

Remarks: * [illegible]

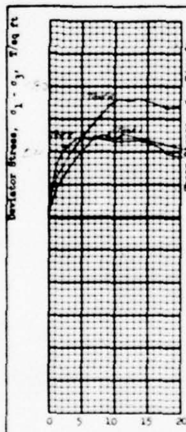
Project: Long Range Delaware River Disposal Area

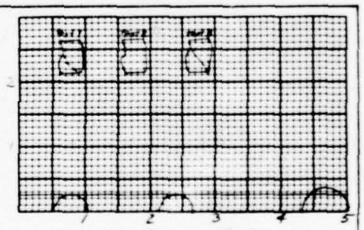
Area: Edgemoor

Boring No. [illegible] | Sample No. [illegible]

Depth: [illegible] | Date: Sept 1967

TRIAXIAL COMPRESSION TEST REPORT





Shear Strength Parameters

ϕ = — °

tan ϕ = —

c = [illegible] T/sq ft

Method of saturation: None

☐ Controlled stress
☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	43.4 %	47.9 %	41.6 %	%
	Void ratio	e_o	1.237	1.477	1.167	
	Saturation	S_o	91.6 %	84.6 %	93.1 %	%
	Dry density, lb/cu ft	γ_d	72.8	65.8	75.2	
Before Shear	Water content	w_c	— %	— %	— %	%
	Void ratio	e_c	—	—	—	
	Saturation	S_c	— %	— %	— %	%
	Final back pressure, T/sq ft	u_o	—	—	—	
Final	Water content	w_f	— %	— %	%	%
	Void ratio	e_f	—	—	—	
Minor principal stress, T/sq ft		σ_3	0.54	2.16	4.32	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.50	0.97	0.72	
Time to failure, min		t_f				
Rate of strain, percent/min						
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.44	0.96	0.71	
Initial diameter, in.		D_o	1.40	1.40	1.40	
Initial height, in.		H_o	3.15	3.19	3.29	

Type of test: Q | Type of specimen: Undisturbed

Classification: Organic CLAY (OH)

LL [illegible] | PL [illegible] | PI 17 | D_{10} < 0.001 | G_s 2.61

Remarks:

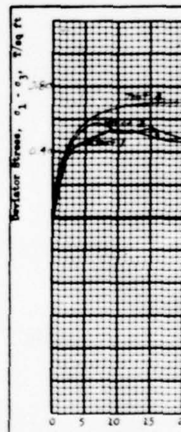
Project: Long Range Delaware River Disposal Area

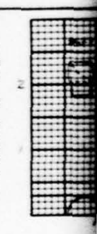
Area: Edgemoor

Boring No. EBB-[illegible] | Sample No. UD3

Depth: 16.[illegible]-19.0' | Date: Sept 1967

TRIAXIAL COMPRESSION TEST REPORT





Shear Strength Parameters

ϕ = — °

tan ϕ = —

c = 0.30 T/sq ft

Method of saturation: None

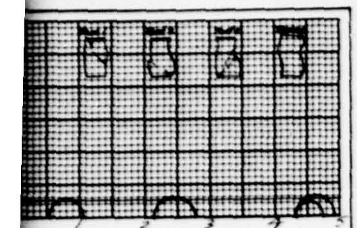
☐ Controlled stress
☒ Controlled strain

Type of test: Q | Type of specimen: Un…

Classification: Organic SILT (…

LL 89 | PL 49 | PI

Remarks: * Stress at 15% strain



No.		1	2	3	3A
ter content	w_o	93.5%	92.2%	95.1%	91.9%
id ratio	e_o	2.544	2.479	2.601	2.484
turation	S_o	92.6%	93.7%	92.1%	93.2%
y density, /cu ft	γ_d	44.4	45.2	48.7	45.1
ter content	w_c	— %	— %	— %	— %
id ratio	e_c	—	—	—	—
turation	S_c	— %	— %	— %	— %
nal back pressure, T/sq ft	u_o	—	—	—	—
ter content	w_f	— %	— %	— %	— %
id ratio	e_f	—	—	—	—
principal s, T/sq ft	σ_3	0.54	2.16	4.32	4.32
viator s, T/sq ft	$(\sigma_1-\sigma_3)_{max}$	0.47	0.61	0.91	0.58
to failure, min	t_f	8.6	8.0	12.3	52
of strain, nt/min		1.03	1.03	1.00	0.99
viator s, T/sq ft	$(\sigma_1-\sigma_3)_{ult}$	*0.44	*0.60	*0.38	*0.42
al diameter, in.	D_o	1.40	1.40	1.40	1.40
al height, in.	H_o	3.17	3.15	3.23	3.15

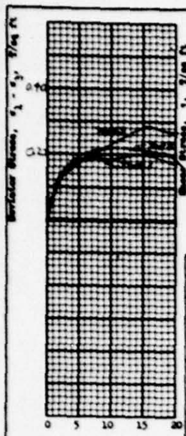
Undisturbed

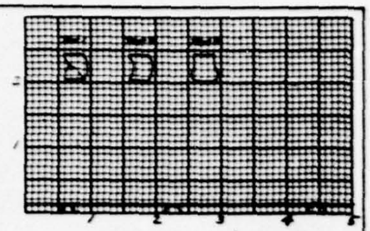
AY (OH)

PI 72	D_{10} <0.001	G_s 2.52

Project	Long Range Delaware River Disposal Area
Area	Edgemoor
Boring No. EBB-5	Sample No. UD 4
Depth 22.0'–24.0'	Date Sept 1967

TRIAXIAL COMPRESSION TEST REPORT





Shear Strength Parameters

φ = — °

tan φ = —

c = 0.12 T/sq ft

Method of saturation: None

☐ Controlled stress

☒ Controlled strain

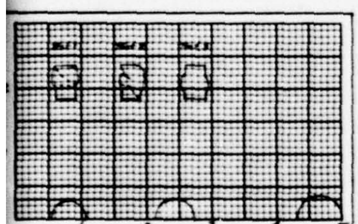
Test No.			1	2	3	
Initial	Water content	w_o	95.7%	97.7%	100.4	%
	Void ratio	e_o	2.647	2.631	2.639	
	Saturation	S_o	91.4%	95.9%	96.6%	%
	Dry density, lb/cu ft	γ_d	43.3	43.5	43.5	
Before Shear	Water content	w_c	— %	— %	— %	%
	Void ratio	e_c	—	—	—	
	Saturation	S_c	— %	— %	— %	%
	Final back pressure, T/sq ft	u_o	—	—	—	
Final	Water content	w_f	— %	— %	— %	%
	Void ratio	e_f	—	—	—	
Minor principal stress, T/sq ft		σ_3	0.54	2.16	4.32	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.194	0.218	0.208*	
Time to failure, min		t_f	8.0	9.8	16.3	
Rate of strain, percent/min			1.05	1.01	1.00	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.200*	0.208*	—	
Initial diameter, in.		D_o	1.4	1.4	1.4	
Initial height, in.		H_o	3.16	3.21	3.33	

Type of test Q	Type of specimen Undisturbed		
Classification	Organic CLAY (OH)		
LL 110	PL 41	PI 69	D_{10} <0.001 / G_s 2.53

Remarks *Stress at 15% Strain

Project	Long Range Delaware River Disposal Area
Area	Edgemoor
Boring No. EBB-6	Sample No. UD1
Depth 4.0'–6.0'	Date Sept 1967

TRIAXIAL COMPRESSION TEST REPORT



No.		1	2	3	
Water content	w_o	92.1%	88.4%	81.5%	%
Void ratio	e_o	2.267	2.457	2.263	
Saturation	S_o	92.0%	91.4%	91.4%	%
Dry density, lb/cu ft	γ_d	48.5	45.1	48.6	
Water content	w_c	— %	— %	— %	%
Void ratio	e_c	—	—	—	
Saturation	S_c	— %	— %	— %	%
Final back pressure, T/sq ft	u_o	—	—	—	
Water content	w_f	— %	— %	— %	%
Void ratio	e_f	—	—	—	
principal ss, T/sq ft	σ_3	0.54	2.16	4.32	
deviator ss, T/sq ft	$(\sigma_1-\sigma_3)_{max}$	0.54	0.57	*0.69	
to failure, min	t_f	9.6	6.2	9.4	
of strain, ent/min		1.03	0.98	1.03	
deviator ss, T/sq ft	$(\sigma_1-\sigma_3)_{ult}$	0.52	*0.49	—	
ial diameter, in.	D_o	1.40	1.40	1.40	
ial height, in.	H_o	3.17	3.31	3.17	

Undisturbed

SILT (OH)

PI 40	D_{10} < 0.001	G_s 2.54

Project	Long Range Delaware River Disposal Area
Area	Edgemoor
Boring No. EBB-9	Sample No. UD2
Depth 12.0'–14.0'	Date Sept 1967

TRIAXIAL COMPRESSION TEST REPORT

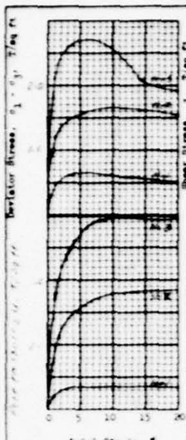
Q TEST FOR:
EBB-2 (UD-2)
EBB-5 (UD-1, 4)
EBB-6 (UD-1, 3)
EBB-8 (UD-3)
EBB-9 (UD-2)

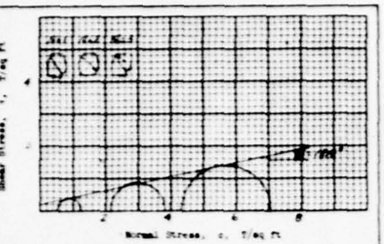
LONG RANGE SPOIL DISPOSAL STUDY

EDGEMOOR DISPOSAL AREA
TEST REPORTS

U. S. ARMY ENGINEER DISTRICT
2 **PHILADELPHIA**

PLATE 28





Shear Strength Parameters

φ = 12.4°

tan φ = 0.220

c = 0.15 T/sq ft

Method of saturation: Backpressure

☐ Controlled stress
☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	86.6 %	84.7 %	95.0 %	%
	Void ratio	e_o	2.434	2.393	2.681	
	Saturation	S_o	96.7 %	96.3 %	90.4 %	%
	Dry density, lb/cu ft	γ_d	46.3	46.9	43.2	
Before Shear	Water content	w_c	80.4 %	68.1 %	59.2 %	%
	Void ratio	e_c	2.050	1.736	1.509	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	7.20	7.20	7.20	
Final	Water content	w_f	80.4 %	68.1 %	59.2 %	%
	Void ratio	e_f	2.050	1.736	1.509	
Minor principal stress, T/sq ft		σ_3	0.54	2.16	4.82	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.67	1.65	2.71	
Time to failure, min		t_f	28.3	49.6	31.8	
Rate of strain, percent/min			0.19	0.19	0.20	
Pore Pressure T/sq ft		u	+0.35	+1.74	+2.88	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.56	1.61	2.61	
Initial diameter, in.		D_o	1.40	1.41	1.40	
Initial height, in.		H_o	3.15	3.15	3.15	

Type of test R | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL 119 | PL 49 | PI 70 | D_{10} < 0.001 | G_s 2.55

Remarks

Project Delaware River Disposal Area Study

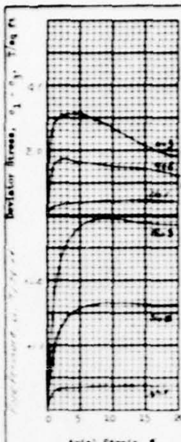
Area Edgemoor Disposal Area

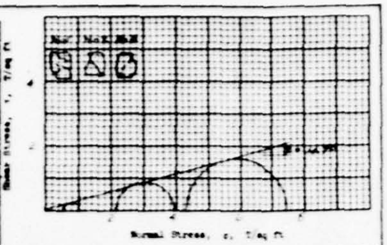
Boring No. EBB-2 | Sample No. UD-2

Depth 16.0'-18.0' | Date Oct 1967

TRIAXIAL COMPRESSION TEST REPORT

Sheet 1 of 2





Shear Strength Parameters

φ = 14.7°

tan φ = 0.262

c = 0.05 T/sq ft

Method of saturation: Backpressure

☐ Controlled stress
☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	101.9 %	98.9 %	101.7 %	%
	Void ratio	e_o	2.764	2.916	2.773	
	Saturation	S_o	90.5 %	84.1 %	90.9 %	%
	Dry density, lb/cu ft	γ_d	41.1	39.5	41.0	
Before Shear	Water content	w_c	94.7 %	81.8 %	65.8 %	%
	Void ratio	e_c	2.349	2.028	1.583	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	7.20	7.20	7.20	
Final	Water content	w_f	94.7 %	81.8 %	65.8 %	%
	Void ratio	e_f	2.349	2.028	1.583	
Minor principal stress, T/sq ft		σ_3	0.59	2.16	4.32	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.48	1.74	3.14	
Time to failure, min		t_f	79.6	142	247	
Rate of strain, percent/min			0.18	0.20	0.20	
Pore Pressure T/sq ft		u	+0.88	+1.39	+2.88	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.47	1.41	2.09	
Initial diameter, in.		D_o	1.39	1.43	1.43	
Initial height, in.		H_o	3.20	3.15	3.15	

Type of test R | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL 134 | PL 51 | PI 83 | D_{10} < 0.001 | G_s 2.48

Remarks

Project Delaware River Disposal Area Study

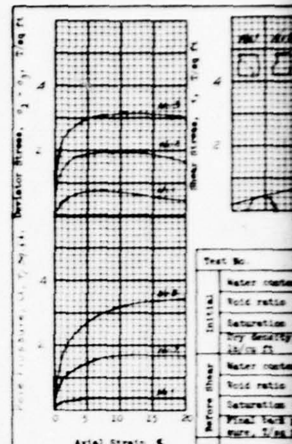
Area Edgemoor Disposal Area

Boring No. EBB-5 | Sample No. UD-1

Depth 2.0'-4.0' | Date Oct 1967

TRIAXIAL COMPRESSION TEST REPORT

Sheet 1 of 2



Shear Strength Parameters

φ = 13.8°

tan φ = 0.245

c = 0.20 T/sq ft

Method of saturation: Backpressure

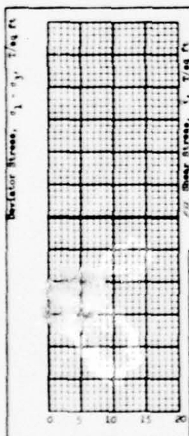
☐ Controlled stress
☒ Controlled strain

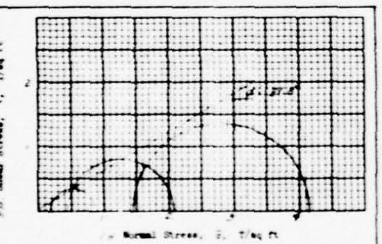
Type of test R | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL 121 | PL 49 | PI 72

Sheet 1 of 2





Shear Strength Parameters

φ = [illegible]°

tan φ = [illegible]

c = 0 T/sq ft

Method of saturation: Backpressure

☐ Controlled stress
☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	%	%	%	%
	Void ratio	e_o				
	Saturation	S_o	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Before Shear	Water content	w_c	%	%	%	%
	Void ratio	e_c				
	Saturation	S_c	%	%	%	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	%	%	%	%
	Void ratio	e_f				
Minor principal stress, T/sq ft Eff		$\bar{\sigma}_3$	0.15	0.42	1.44	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$				
Time to failure, min		t_f				
Rate of strain, percent/min						
Major Principal Stress, T/sq ft Eff		$\bar{\sigma}_1$	0.56	2.07	4.15	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$				
Initial diameter, in.		D_o				
Initial height, in.		H_o				

Type of test $\bar{R}$ | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL 119 | PL 49 | PI 70 | D_{10} < 0.001 | G_s 2.55

Remarks See Sheet 1 of 2 for other data

Project Delaware River Disposal Area Study

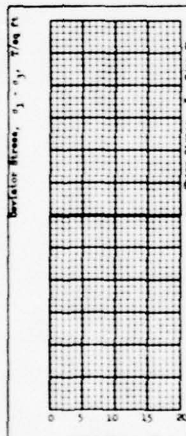
Area Edgemoor Disposal Area

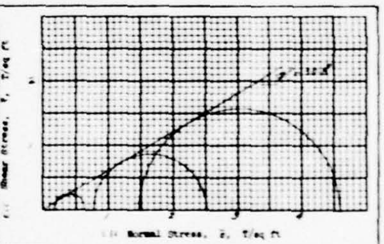
Boring No. EBB-2 | Sample No. UD-2

Depth 16.0'-18.0 | Date Oct 1967

TRIAXIAL COMPRESSION TEST REPORT

Sheet 2 of 2





Shear Strength Parameters

φ = 30.8°

tan φ = 0.595

c = 0 T/sq ft

Method of saturation: Backpressure

☐ Controlled stress
☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	%	%	%	%
	Void ratio	e_o				
	Saturation	S_o	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Before Shear	Water content	w_c	%	%	%	%
	Void ratio	e_c				
	Saturation	S_c	%	%	%	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	%	%	%	%
	Void ratio	e_f				
Minor principal stress, T/sq ft Eff		$\bar{\sigma}_3$	0.16	0.77	1.44	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$				
Time to failure, min		t_f				
Rate of strain, percent/min						
Major Principal Stress, T/sq ft Eff		$\bar{\sigma}_1$	0.64	2.52	4.58	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$				
Initial diameter, in.		D_o				
Initial height, in.		H_o				

Type of test $\bar{R}$ | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL 134 | PL 51 | PI 83 | D_{10} < 0.001 | G_s 2.48

Remarks See Sheet 1 of 2 for other data

Project Delaware River Disposal Area Study

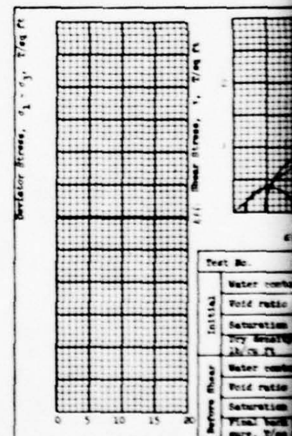
Area Edgemoor Disposal Area

Boring No. EBB-5 | Sample No. UD-1

Depth 2.0'-4.0' | Date Oct 1967

TRIAXIAL COMPRESSION TEST REPORT

Sheet 2 of 2



Shear Strength Parameters

φ = 35.9°

tan φ = 0.725

c = 0 T/sq ft

Method of saturation: Backpressure

☐ Controlled stress
☒ Controlled strain

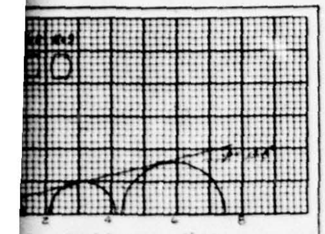
Type of test R | Type of specimen Undist

Classification Organic CLAY (OH)

LL 121 | PL 49

Remarks See Sheet 1 of 2 for other data

Sheet 2 of 2



Normal Stress, σ, T/sq ft

		1	2	3	
...ntent	w_o	99.4 %	100.1 %	99.7 %	%
...tio	e_o	2.648	2.797	2.666	
...ion	S_o	94.6 %	92.2 %	94.2 %	%
...ity, ...	γ_d	43.1	42.1	42.9	
...ntent	w_c	92.5 %	75.7 %	64.4 %	%
...tio	e_c	2.330	1.908	1.622	
...ion	S_c	100 %	100 %	100 %	%
...ck pres- ...sq ft	u_o	7.20	7.20	7.20	
...ntent	w_f	92.5 %	75.7 %	64.4 %	%
...tio	e_f	2.330	1.908	1.622	
...ipal ...q ft	σ_3	0.54	2.16	4.32	
...q ft	$(\sigma_1-\sigma_3)_{max}$	0.77	1.98	3.16	
...lure, min	t_f	42.5	53.1	55.4	
...ain, ...		0.18	0.19	0.19	
...ure ...	u	+0.38	+1.68	+3.23	
...q ft	$(\sigma_1-\sigma_3)_{ult}$	0.60	1.88	3.12	
...meter, in.	D_o	1.41	1.42	1.41	
...ight, in.	H_o	3.25	3.23	3.15	

...isturbed

...OH)

... 72 | D_{10} < 0.001 | G_s 2.52

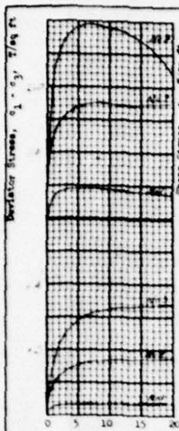
...ject Delaware River Disposal Area Study

... Edgemoor Disposal Area

...ring No. EBB-5 | Sample No. UD-4

...pth 22.0'-24.0' | Date Oct. 1967

TRIAXIAL COMPRESSION TEST REPORT



Axial Strain, %

Shear Strength Parameters

φ = 14.5°

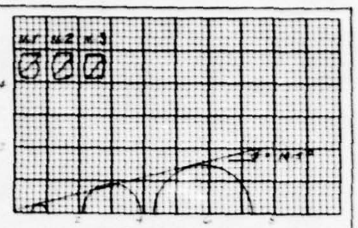
tan φ = 0.258

c = 0.05 T/sq ft

Method of saturation: Backpressure

☐ Controlled stress

☒ Controlled strain



Normal Stress, σ, T/sq ft

Test No.			1	2	3	
Initial	Water content	w_o	93.3 %	95.9 %	92.3 %	%
	Void ratio	e_o	2.567	2.598	2.541	
	Saturation	S_o	91.9 %	95.7 %	91.9 %	%
	Dry density, lb/cu ft	γ_d	44.3	44.0	44.6	
Before Shear	Water content	w_c	81.5 %	63.7 %	55.1 %	%
	Void ratio	e_c	2.061	1.612	1.395	
	Saturation	S_c	100 %	100 %	100 %	%
	Final back pressure, T/sq ft	u_o	7.20	7.20	7.20	
Final	Water content	w_f	81.5 %	63.7 %	55.1 %	%
	Void ratio	e_f	2.061	1.612	1.395	
Minor principal stress, T/sq ft		σ_3	0.54	2.16	4.32	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.47	1.75	2.97	
Time to failure, min		t_f	29.5	51.7	37.0	
Rate of strain, percent/min			0.18	0.18	0.19	
Pore Pressure T/sq ft		u	+0.39	+1.68	+3.12	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.39	1.71	2.85	
Initial diameter, in.		D_o	1.40	1.41	1.40	
Initial height, in.		H_o	3.15	3.28	3.17	

Type of test R | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL 110 | PL 41 | PI 69 | D_{10} < 0.001 | G_s 2.53

Remarks

Sheet 1 of 2

Project Delaware River Disposal Area Study

Area Edgemoor Disposal Area

Boring No. EBB-6 | Sample No. UD-1

Depth 40'-60' | Date Oct. 1967

TRIAXIAL COMPRESSION TEST REPORT

eff Normal Stress, σ̄, T/sq ft

		1	2	3	
... content	w_o	%	%	%	%
... ratio	e_o				
...ration	S_o	%	%	%	%
...nsity, ...ft	γ_d				
... content	w_c	%	%	%	%
... ratio	e_c				
...ration	S_c	%	%	%	%
... back pres- ... T/sq ft	u_o				
... content	w_f	%	%	%	%
... ratio	e_f				
...cipal ...sq ft eff	$\bar{\sigma}_3$	0.16	0.48	1.09	
...tor ...sq ft	$(\sigma_1-\sigma_3)_{max}$				
...ailure, min	t_f				
...train, ...in					
...cipal ...sq ft eff	$\bar{\sigma}_1$	0.92	2.46	4.25	
...sq ft	$(\sigma_1-\sigma_3)_{ult}$				
...iameter, in.	D_o				
...eight, in.	H_o				

...ndisturbed

(OH)

... 72 | D_{10} < 0.001 | G_s 2.52

...roject Delaware River Disposal Area Study

... Edgemoor Disposal Area

...ring No. EBB-5 | Sample No. UD-4

...pth 22.0'-24.0' | Date Oct. 1967

TRIAXIAL COMPRESSION TEST REPORT

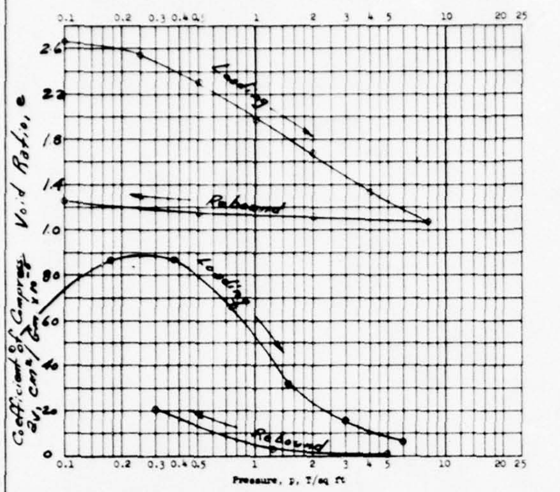
R TEST FOR:
EBB-2 (UD-2)
EBB-5 (UD-1,4)
EBB-6 (UD-1) Sheet 1 of 2

LONG RANGE SPOIL DISPOSAL STUDY

EDGEMOOR DISPOSAL AREA TEST REPORTS

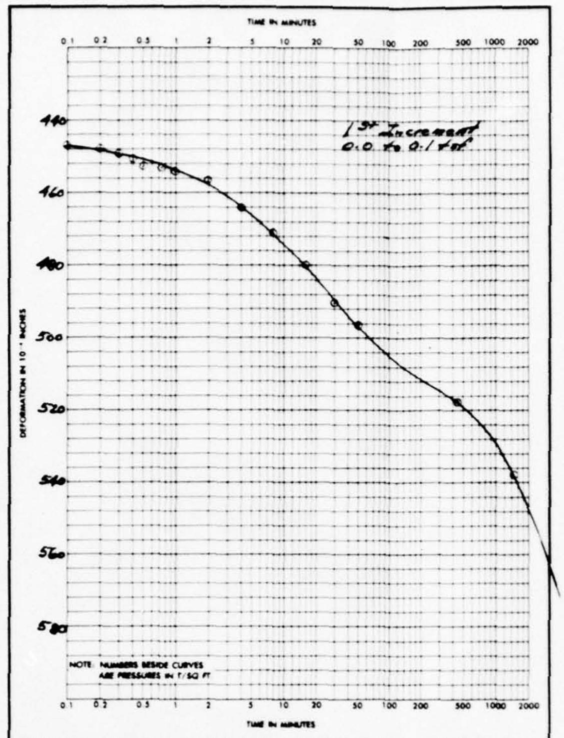
U.S. ARMY ENGINEER DISTRICT PHILADELPHIA

2

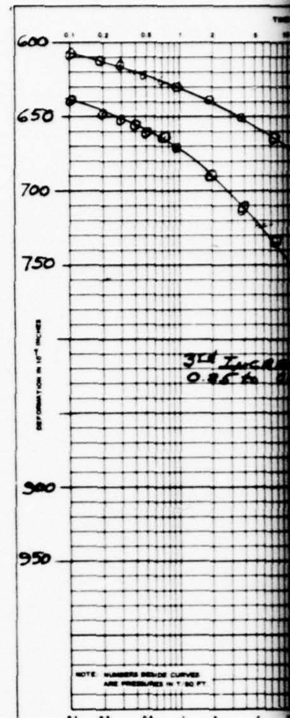


Type of Specimen Undisturbed		Before Test		After Test	
Diam 2.6 in.	Ht 0.75 in.	Water Content, w_o	101.0 %	w_f	57.1 %
Overburden Pressure, p_o 0.20 T/sq ft		Void Ratio, e_o	2.704	e_f	1.245
Preconsol. Pressure, p_c 0.30 T/sq ft		Saturation, S_o	92.3 %	S_f	100+ %
Compression Index, C_c 1.07		Dry Density, γ_d	41.6 lb/ft³		
Classification Organic CLAY (OH)		k_{20} at e_o =	× 10 cm/sec		
LL Wet 120 OD 78	G_s 2.47	Project Long Range Delaware River Disposal Area			
PL 43 44	D_{10} <0.001				
Remarks		Area Edgemoor			
		Boring No. EBB-3		Sample No. UD-2	
		Depth 120'-140'		Date Oct 1967	

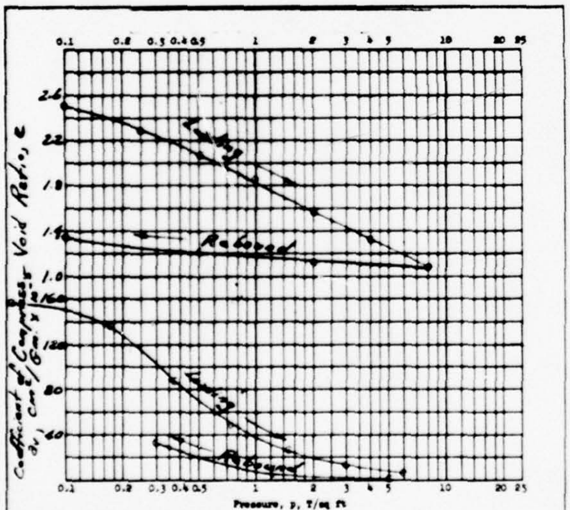
CONSOLIDATION TEST REPORT



Project Long Range Delaware River Disposal Area Study
Area Edgemoor
Boring No. EBB-3 Sample No. UD-2 Depth 120'-140' Date Dec. 1967
ENG FORM 1 MAY 63 2088 PREVIOUS EDITIONS ARE OBSOLETE CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)

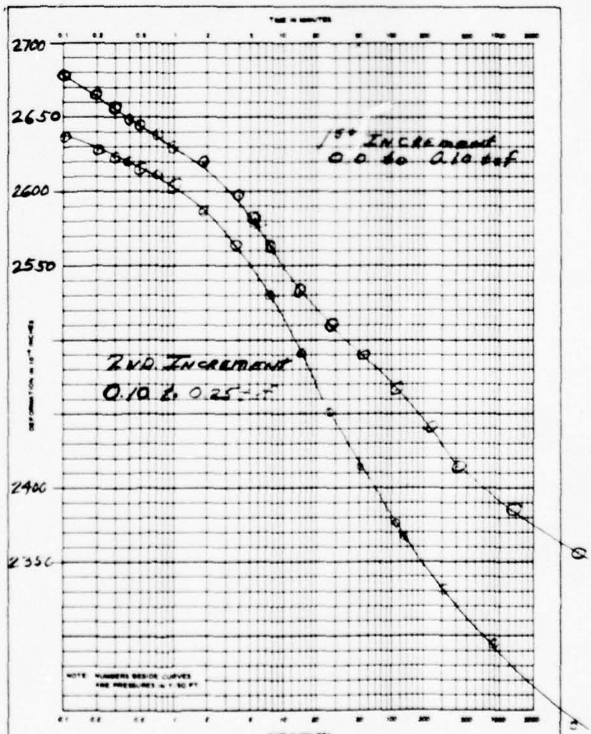


Project Long Range Delaware
Area Edgemoor
Boring No. EBB-3 Sample No. UD-2
CONSOLIDATION T

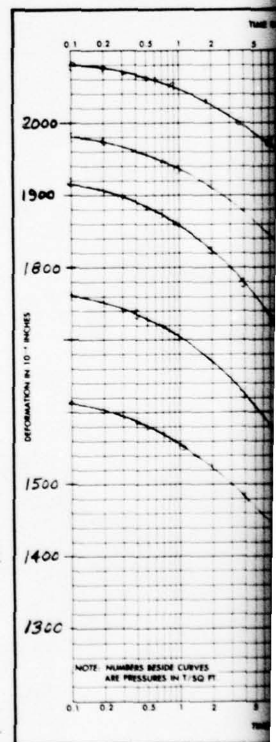


Type of Specimen Undisturbed		Before Test		After Test	
Diam 3.0 in.	Ht 0.75 in.	Water Content, w_o	103.9 %	w_f	54.8 %
Overburden Pressure, p_o 0.15 T/sq ft		Void Ratio, e_o	2.651	e_f	1.337
Preconsol. Pressure, p_c 0.30 T/sq ft		Saturation, S_o	98.4 %	S_f	100+ %
Compression Index, C_c 0.82		Dry Density, γ_d	42.9 lb/ft³		
Classification Organic CLAY (OH)		k_{20} at e_o =	× 10 cm/sec		
LL Wet 107 OD 73	G_s 2.51	Project Long Range Delaware River Disposal Area			
PL 43 42	D_{10} <0.001				
Remarks		Area Edgemoor			
		Boring No. EBB-4		Sample No. UD-1	
		Depth 8.0'-10.0'		Date Oct 1967	

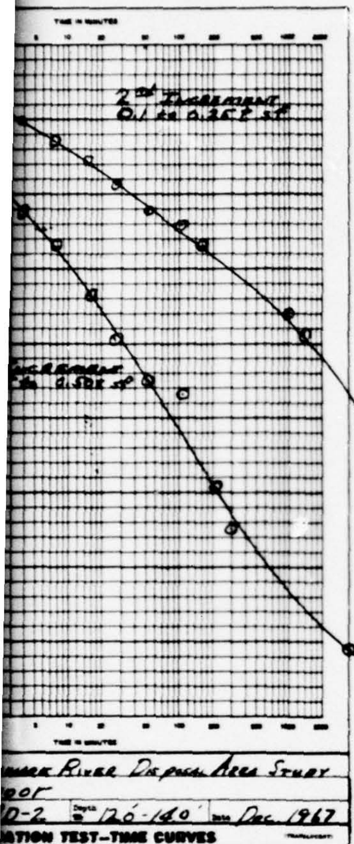
CONSOLIDATION TEST REPORT

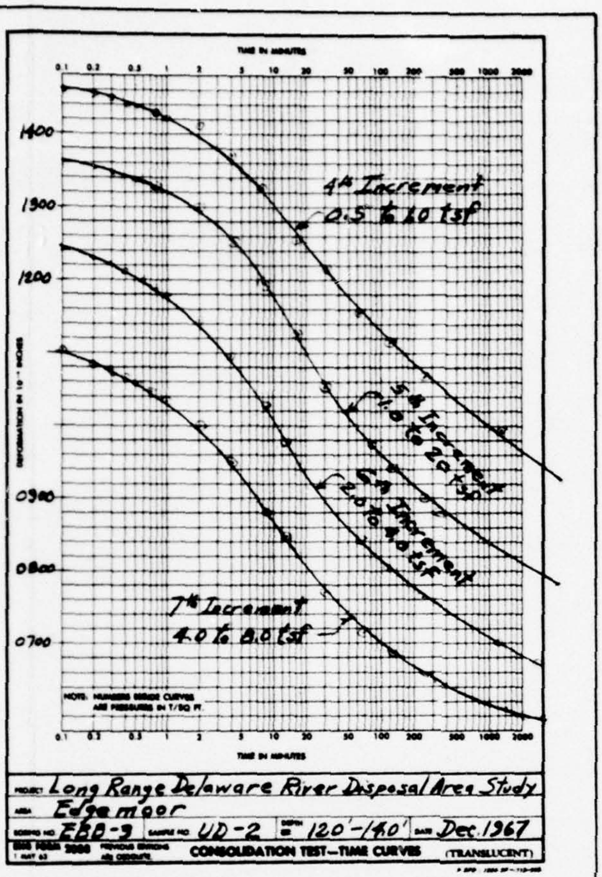


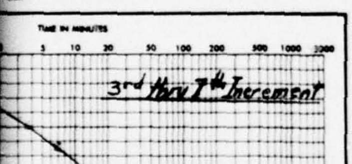
Project Long Range Delaware River Disposal Area Study
Area Edgemoor
Boring No. EBB-4 Sample No. UD-1 Depth 8.0'-10.0' Date Dec 1967
CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



Project Long Range Delawar
Area Edgemoor
Boring No. EBB-4 Sample No. UD-1
ENG FORM 1 MAY 63 2088 PREVIOUS EDITIONS ARE OBSOLETE CONSOL







CONSOLIDATION TEST FOR:
EBB-3(UD-2)
EBB-4(UD-1)

LONG RANGE SPOIL DISPOSAL STUDY

EDGEMOOR DISPOSAL AREA
TEST REPORTS

U. S. ARMY ENGINEER DISTRICT
PHILADELPHIA

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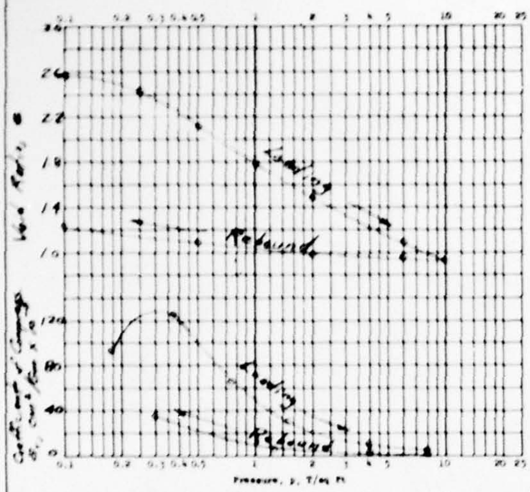
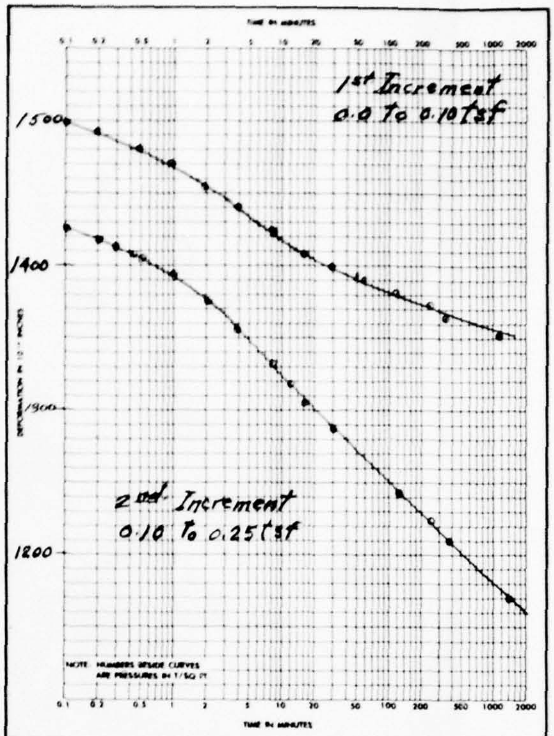
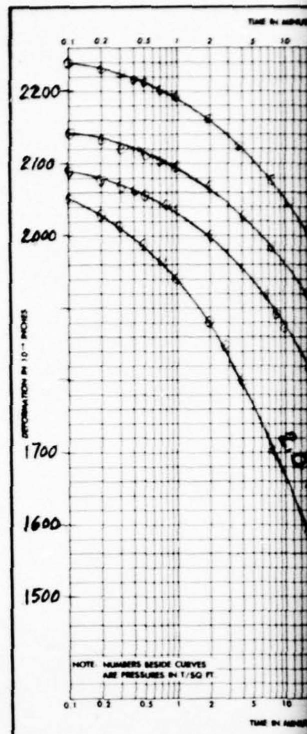


Type of Specimen Undisturbed		Before Test		After Test	
Diam 2.6 in.	Ht 0.75 in.	Water Content, w_o	108.4 %	w_f	57.1 %
Overburden Pressure, p_o 0.25 T/sq ft		Void Ratio, e_o	2.643	e_f	1.240
Preconsol. Pressure, p_c 0.29 T/sq ft		Saturation, S_o	78.8 %	S_f	100 %
Compression Index, C_c 0.70		Dry Density, γ_d	42.6 lb/ft³		
Classification Organic CLAY (OH) w/ fine ...		k_{20} at e_o =	× 10⁻ cm/sec		
LL 122	G_s 2.47	Project Long Range Delaware River Disposal Area			
PL 45	D_{10} < 0.001				
Remarks		Area Edgemoor			
		Boring No. EBB-5		Sample No. UD-3	
		Depth 16.0'-18.0'		Date Oct 1967	

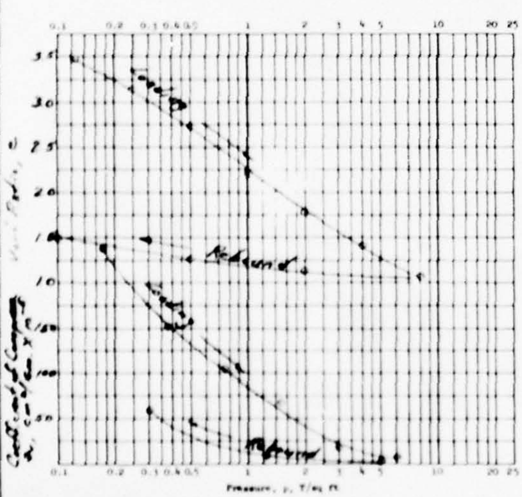
CONSOLIDATION TEST REPORT



PROJECT Long Range Delaware River Disposal Area Study
AREA Edgemoor
BORING NO. EBB-5 SAMPLE NO. UD-3 DEPTH 16.0'-18.0' DATE Dec. 1967
ENG FORM 2088, 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE — CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)

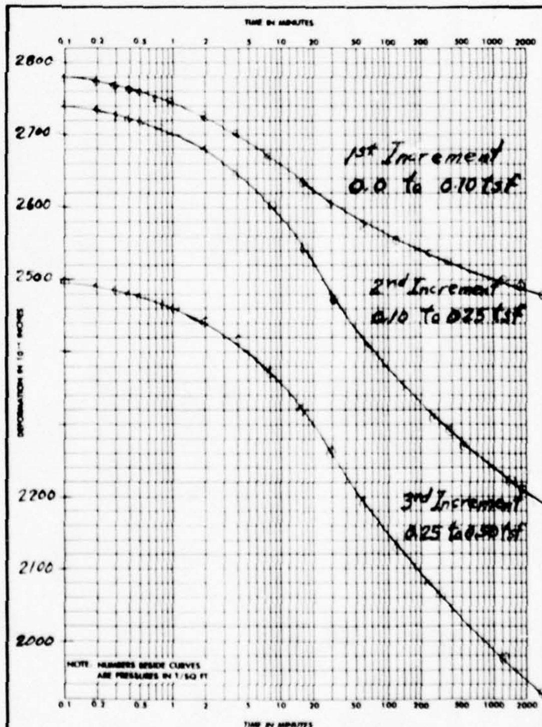


PROJECT Long Range Delaware Ri
AREA Edgemoor
BORING NO. EBB-5 SAMPLE NO. UD-3
ENG FORM 2088, 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE — CONSOLIDATION

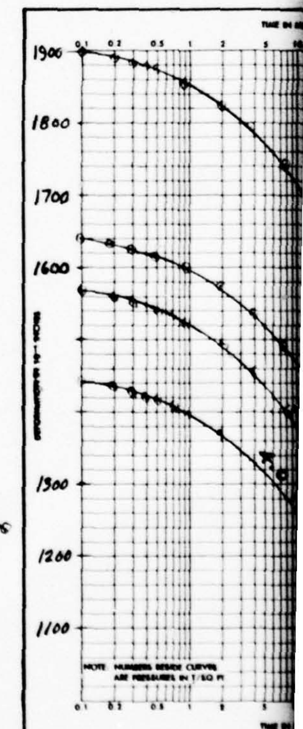


Type of Specimen Undisturbed		Before Test		After Test	
Diam 2.60 in.	Ht 0.75 in.	Water Content, w_o	147.4 %	w_f	68.1 %
Overburden Pressure, p_o 0.07 T/sq ft		Void Ratio, e_o	3.686	e_f	1.497
Preconsol. Pressure, p_c 0.18 T/sq ft		Saturation, S_o	99.2 %	S_f	100+ %
Compression Index, C_c 1.45		Dry Density, γ_d	33.0 lb/ft³		
Classification Organic CLAY (OH) w/ ...		k_{20} at e_o =	× 10⁻ cm/sec		
LL 134	G_s 2.40	Project Long Range Delaware River Disposal Area			
PL 51	D_{10} < 0.001				
Remarks		Area Edgemoor			
		Boring No. EBB-5		Sample No. UD-1	
		Depth 2.0'-4.0'		Date Oct 1967	

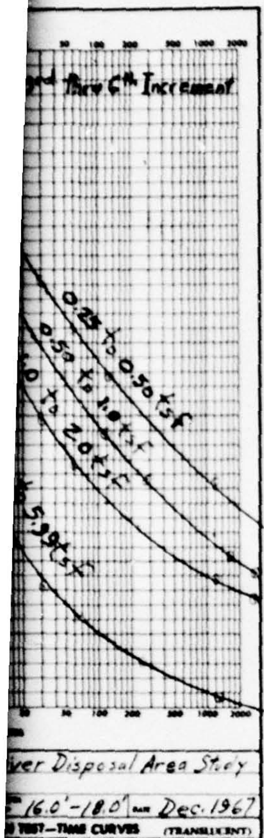
CONSOLIDATION TEST REPORT

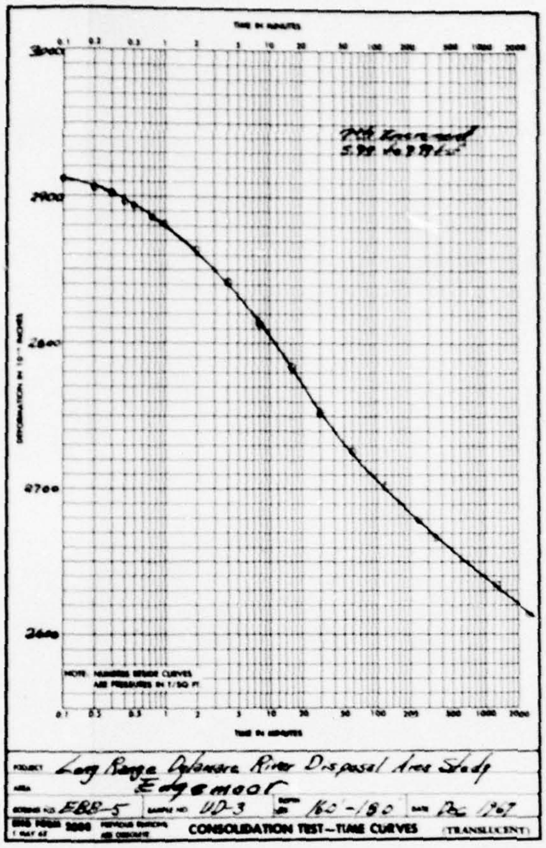


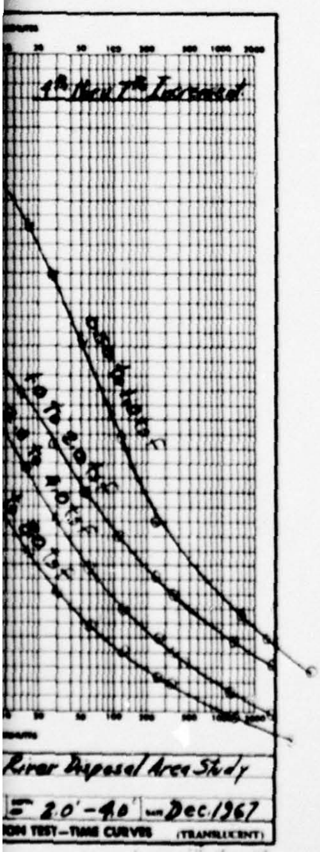
PROJECT Long Range Delaware River Disposal Area Study
AREA Edgemoor
BORING NO. EBB-5 SAMPLE NO. UD-1 DEPTH 2.0'-4.0' DATE Dec 1967
ENG FORM 2088, 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE — CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



PROJECT Long Range Delaware
AREA Edgemoor
BORING NO. EBB-5 SAMPLE NO. UD-1
ENG FORM 2088, 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE — CONSOLIDAT







CONSOLIDATION TEST FOR:
EBB-5(UD-1,3)

LONG RANGE SPOIL DISPOSAL STUDY

EDGEMOOR DISPOSAL AREA TEST REPORTS

U. S. ARMY ENGINEER DISTRICT PHILADELPHIA

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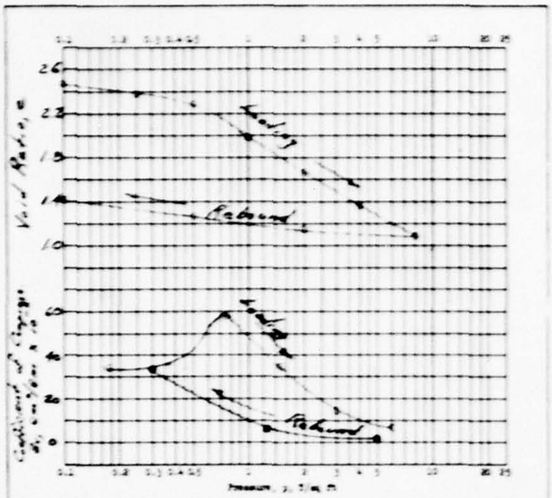
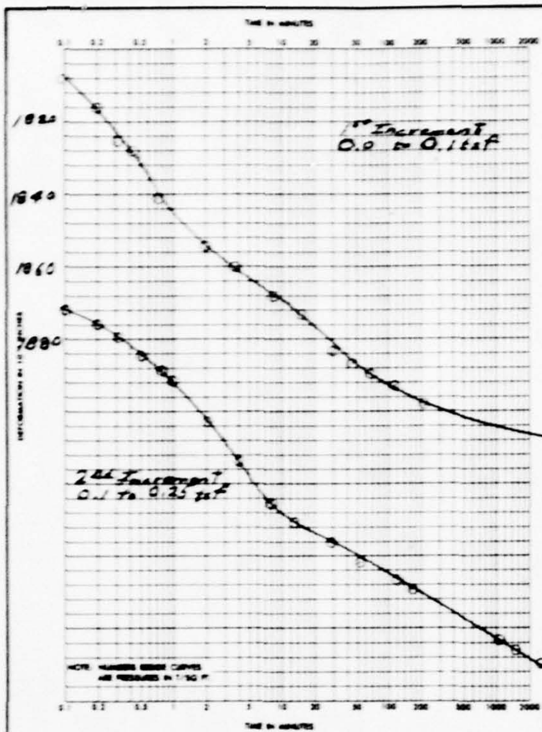
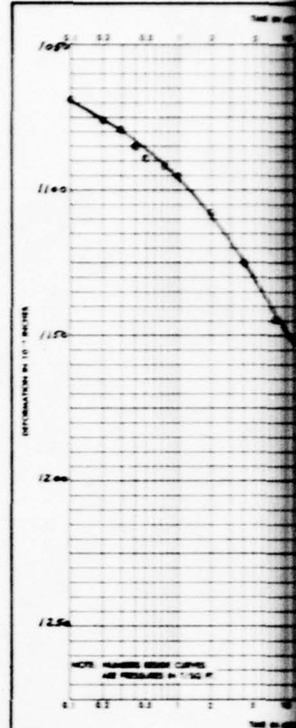


Type of Specimen: Undisturbed	Before Test		After Test	
Diam 3.0 in. Ht 0.75 in.	Water Content, w_o	101.4 %	w_f	61.4 %
Overburden Pressure, p_o 0.49 T/sq ft	Void Ratio, e_o	2.482	e_f	1.405
Precompr. Pressure, p_c 0.48 T/sq ft	Saturation, S_o	100 %	S_f	100+ %
Compression Index, C_c 1.02	Dry Density, γ_d	44 lb/ft³		
Classification Organic Clay (OH)	k_{20} at e_o =	× 10⁻⁸ cm/sec		
LL Nat 134 OD 73 G_s 2.46	Project Long Range Delaware River Disposal Area			
PL 44 42 D_{10} <0.001				
Remarks	Area Edgemoor			
	Boring No. EBB-5	Sample No. UD-6		
	Depth 34.0-36.0'	Date Oct 1967		

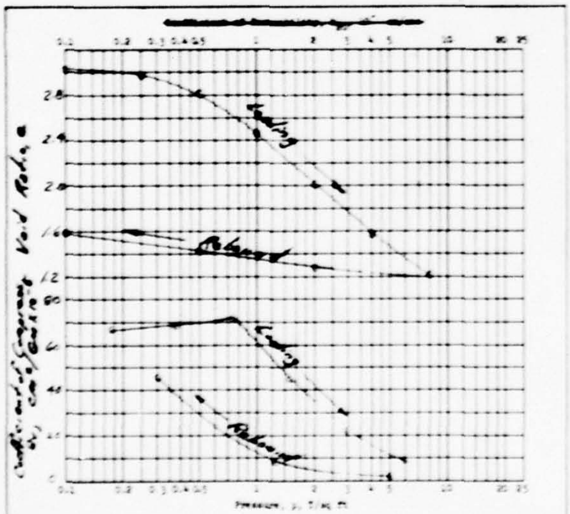
CONSOLIDATION TEST REPORT



Project Long Range Delaware River Disposal Area Study
Area Edgemoor
Boring No. EBB-5 Sample No. UD-6 Depth 34.0-36.0 Date Dec 1967
ENG FORM 2090 CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)

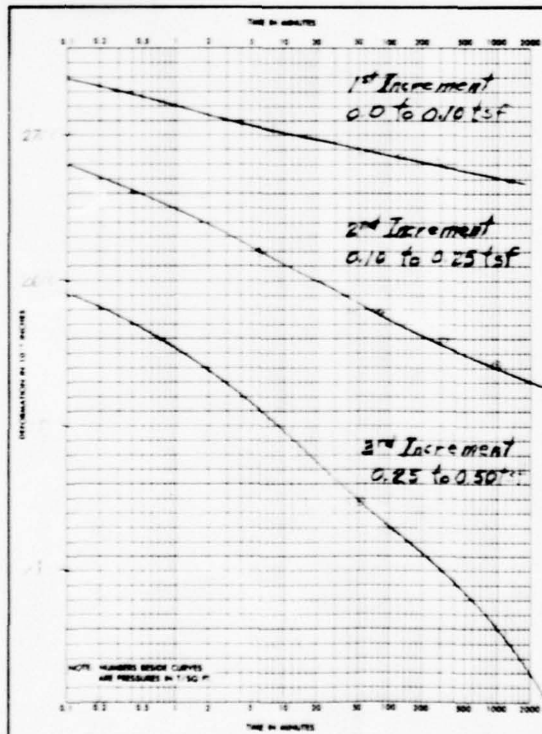


Project Long Range Delaware R...
Area Edgemoor
Boring No. EBB-5 Sample No. UD-6
ENG FORM 2090 CONSOLIDATI...

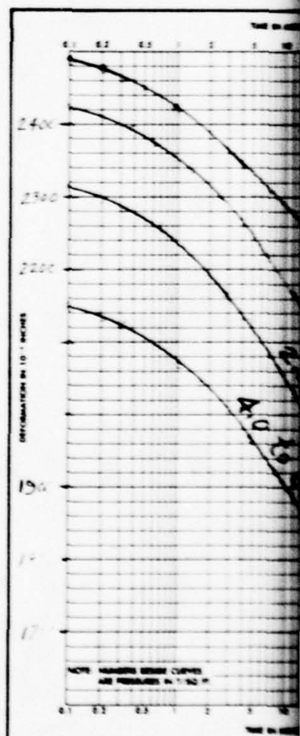


Type of Specimen: Undisturbed	Before Test		After Test	
Diam 3.0 in. Ht 0.75 in.	Water Content, w_o	132.7 %	w_f	79.0 %
Overburden Pressure, p_o 0.43 T/sq ft	Void Ratio, e_o	3.191	e_f	1.573
Precompr. Pressure, p_c 0.50 T/sq ft	Saturation, S_o	95.5 %	S_f	100+ %
Compression Index, C_c 1.43	Dry Density, γ_d	34 lb/ft³		
Classification Organic Clay (OH) w/ trace organic matter	k_{20} at e_o =	× 10⁻⁸ cm/sec		
LL 164 G_s 2.26	Project Long Range Delaware River Disposal Area			
PL 70 D_{10} <0.001				
Remarks	Area Edgemoor			
	Boring No. EBB-6	Sample No. UD-4		
	Depth 29.0'-31.0	Date Oct 1967		

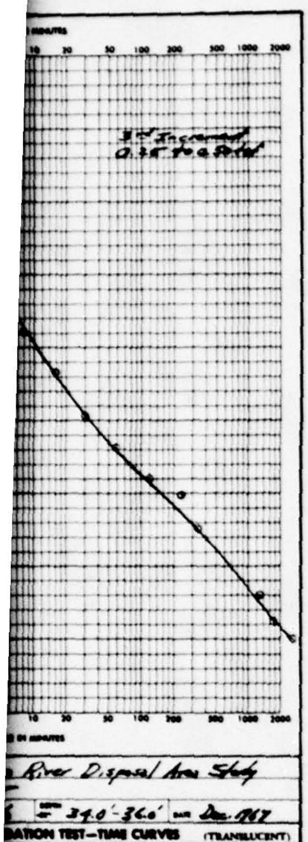
CONSOLIDATION TEST REPORT

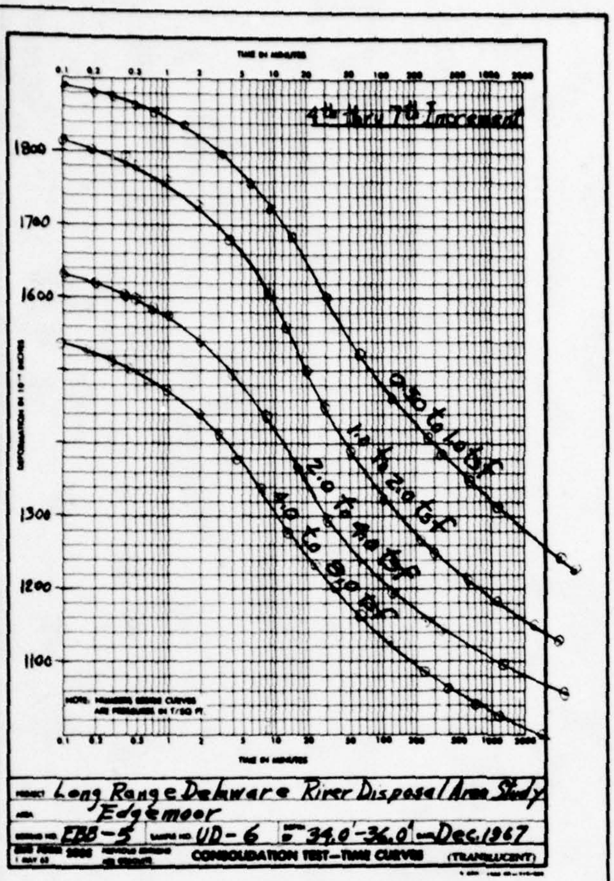


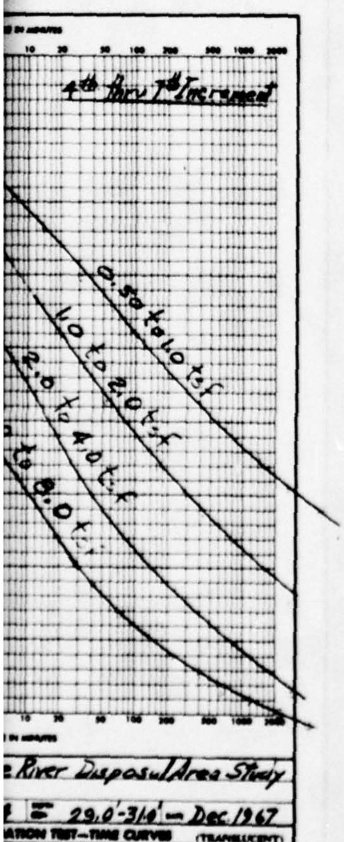
Project Long Range Delaware River Disposal Area Study
Area Edgemoor
Boring No. EBB-6 Sample No. UD-4 Depth 29.0-31.0 Date Dec 1967
ENG FORM 2090 CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



Project Long Range Delaware R...
Area Edgemoor
Boring No. EBB-6 Sample No. UD-4
ENG FORM 2090 CONSOLIDATI...



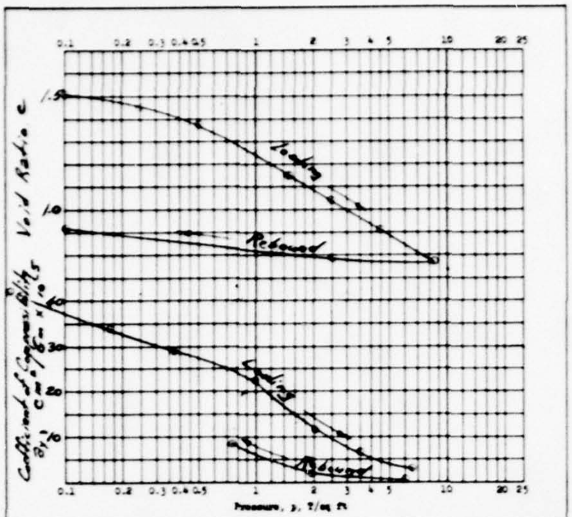




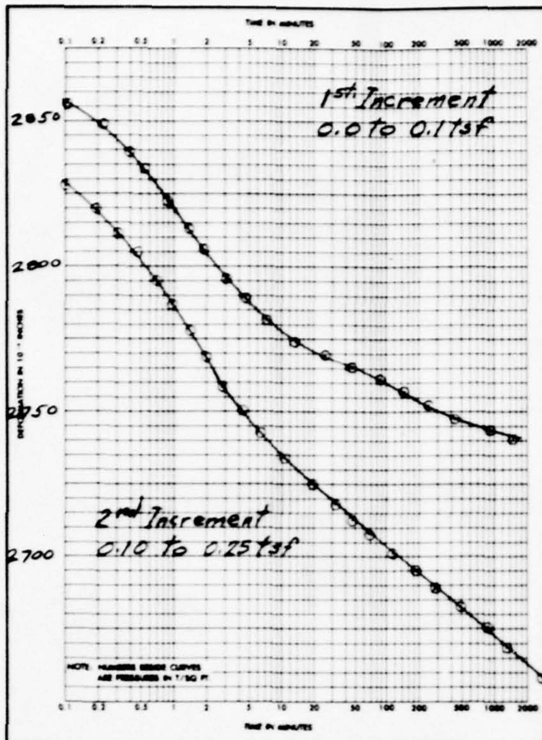
CONSOLIDATION TEST FOR:

EBB-5 (UD-6)
EBB-6 (UD-4)

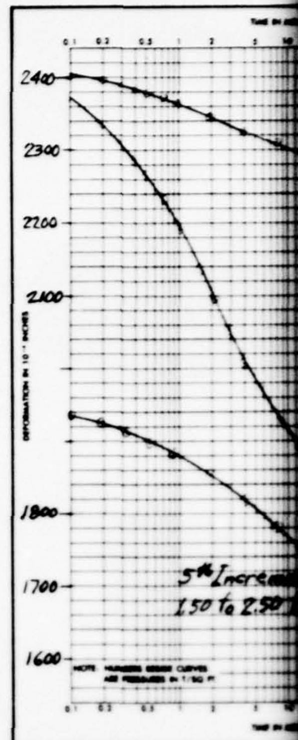
LONG RANGE SPOIL DISPOSAL STUDY
EDGEMOOR DISPOSAL AREA TEST REPORTS
U. S. ARMY ENGINEER DISTRICT PHILADELPHIA



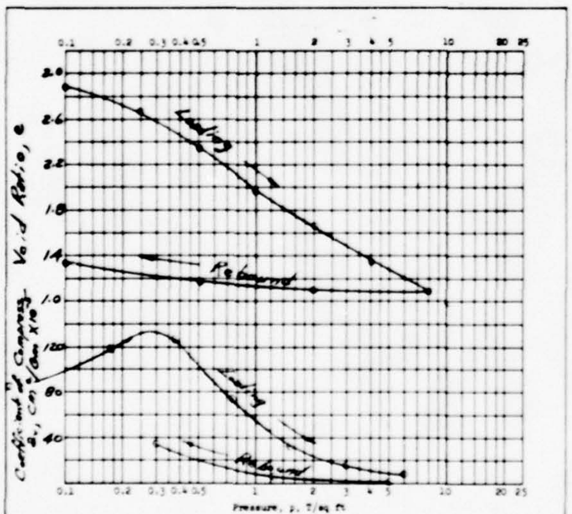
Type of Specimen Undisturbed		Before Test		After Test	
Diam 4.25 in.	Ht 1.00 in.	Water Content, w_o	63.6 %	w_f	44.7 %
Overburden Pressure, p_o 0.43 T/sq ft		Void Ratio, e_o	1.544	e_f	0.914
Precons. Pressure, p_c 0.53 T/sq ft		Saturation, S_o	96.5 %	S_f	100+ %
Compression Index, C_c 0.51		Dry Density, γ_d	57.4 lb/ft³		
Classification Organic SILT (OH)		k_{20} at e_o =	× 10 cm/sec		
LL Nat 56 O.D. 46	G_s 2.34	Project Long Range Delaware River Disposal Area			
PL 36 34	D_{10} < 0.001				
Remarks		Area Edgemoor			
		Boring No. EBB-7		Sample No. UD-4	
		Depth ft 27.0 - 29.0		Date Oct. 1967	
		CONSOLIDATION TEST REPORT			



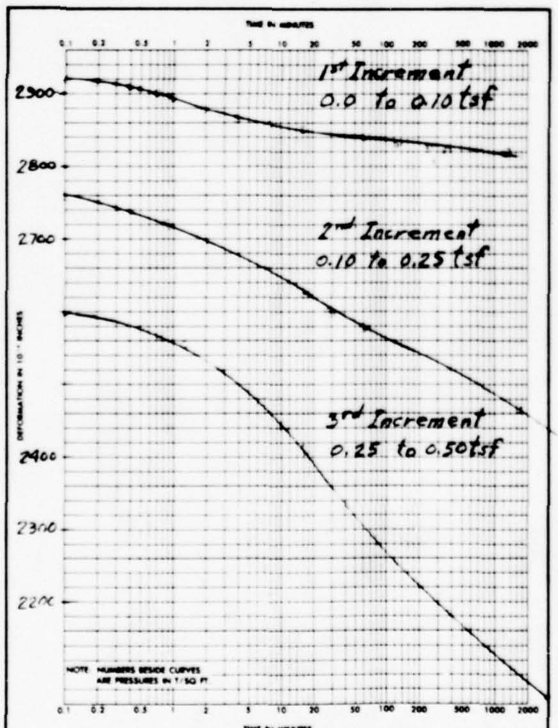
PROJECT Long Range Delaware River Disposal Area Study
AREA Edgemoor
BORING NO. EBB-7 SAMPLE NO. UD-4 DEPTH 27.0'-29.0' DATE Dec. 1967
ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



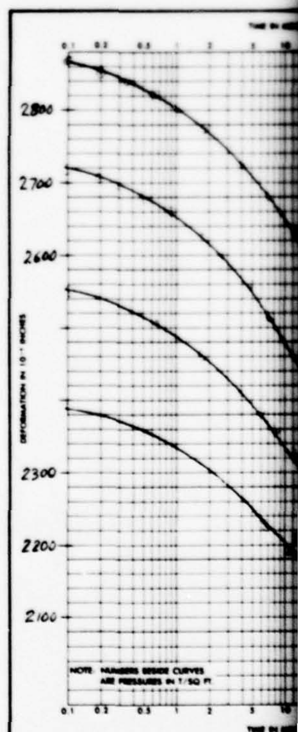
PROJECT Long Range Delaware R
— Edgemoor
EBB-7 UD-4
CONSOLIDAT



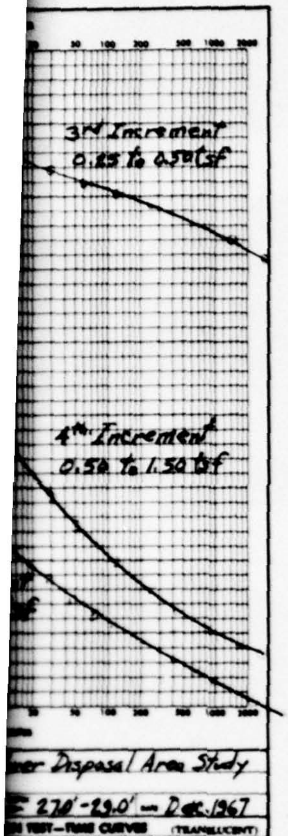
Type of Specimen Undisturbed		Before Test		After Test	
Diam 2.6 in.	Ht 0.75 in.	Water Content, w_o	111.5 %	w_f	60.1 %
Overburden Pressure, p_o 0.27 T/sq ft		Void Ratio, e_o	2.918	e_f	1.323
Precons. Pressure, p_c 0.29 T/sq ft		Saturation, S_o	95.5 %	S_f	100+ %
Compression Index, C_c 1.00		Dry Density, γ_d	37.6 lb/ft³		
Classification Organic CLAY (OH)		k_{20} at e_o =	× 10 cm/sec		
LL 130	G_s 2.50	Project Long Range Delaware River Disposal Area			
PL 45	D_{10} < 0.001				
Remarks		Area Edgemoor			
		Boring No. EBB-7		Sample No. UD-2	
		Depth ft 17.0'-19.0'		Date Oct 1967	
		CONSOLIDATION TEST REPORT			

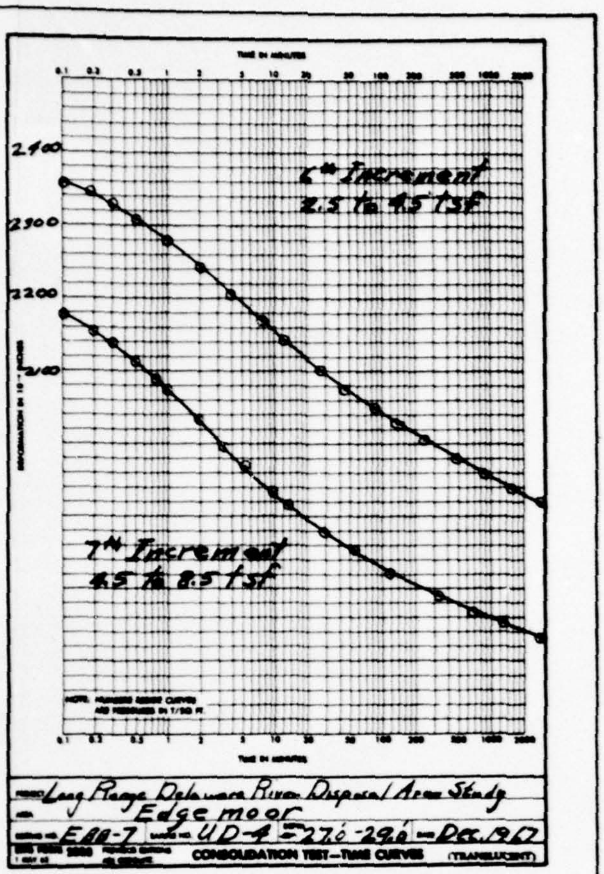


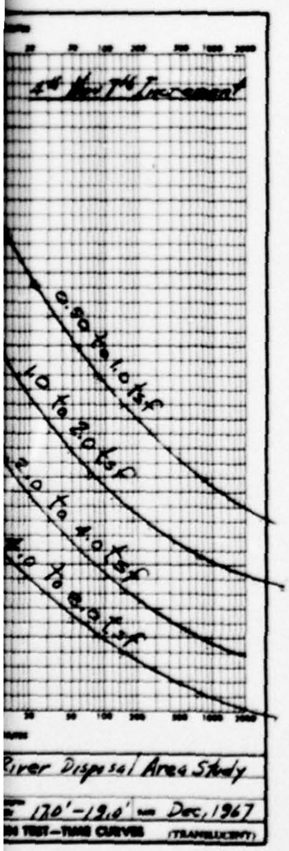
PROJECT Long Range Delaware River Disposal Area Study
AREA Edgemoor
BORING NO. EBB-7 SAMPLE NO. UD-2 DEPTH 17.0'-19.0' DATE Dec. 1967
ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



PROJECT Long Range Delaware R
AREA Edgemoor
BORING NO. EBB-7 SAMPLE NO. UD-2
CONSOLIDAT







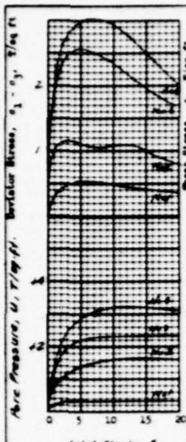
CONSOLIDATION TEST FOR:
EBB-7 (UD-2, 4)

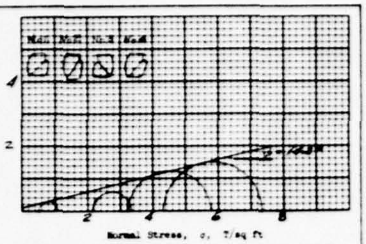
LONG RANGE SPOIL DISPOSAL STUDY

EDGEMOOR DISPOSAL AREA TEST REPORTS

U. S. ARMY ENGINEER DISTRICT PHILADELPHIA

2





Test No.			1	2	3	4
Initial	Water content	w_0	92.0 %	87.9 %	86.1 %	89.7 %
	Void ratio	e_0	2.529	2.342	2.318	2.419
	Saturation	S_0	89.0 %	91.6 %	90.6 %	89.7 %
	Dry density, lb/cu ft	γ_d	43.2	45.6	45.9	44.5
Before Shear	Water content	w_c	79.6 %	61.8 %	58.1 %	53.8 %
	Void ratio	e_c	1.942	1.509	1.417	1.314
	Saturation	S_c	100 %	100 %	100 %	100 %
	Final back pressure, T/sq ft	u_0	7.20	7.20	7.20	7.20
Final	Water content	w_f	79.6 %	61.8 %	58.1 %	53.8 %
	Void ratio	e_f	1.942	1.509	1.417	1.314
Minor principal stress, T/sq ft		σ_3	0.54	2.16	3.24	4.32
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$	0.54	1.17	2.56	3.03
Time to failure, min		t_f	29.6	16.6	21.2	33.3
Rate of strain, percent/min			0.18	0.19	0.20	0.20
Pore Pressure T/Sq ft		U	+0.33	+1.26	+2.15	+2.95
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$	0.42	1.05	1.99	2.55
Initial diameter, in.		D_0	1.40	1.39	1.40	1.39
Initial height, in.		H_0	3.15	3.15	3.15	3.15

Shear Strength Parameters

φ = 14.2°

tan φ = 0.250

c = 0.10 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Type of test R | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL Nat 127 OD 76 | PL Nat 51 OD 55 | PI Nat 76 OD 21 | D_{10} <0.001 | G_s 2.44

Remarks

Project Delaware River Disposal Area Study

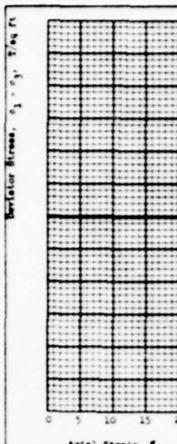
Area Oldmans No1 Disposal Area

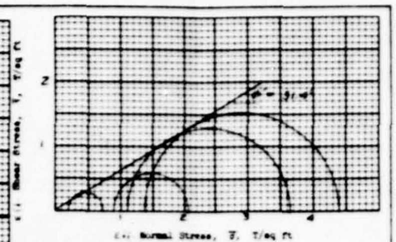
Boring No. EAB-4 | Sample No. UD-1

Depth 4.0'-6.0' | Date Oct. 1967

Sheet 1 of 2

TRIAXIAL COMPRESSION TEST REPORT





Test No.			1	2	3	4
Initial	Water content	w_0	%	%	%	%
	Void ratio	e_0				
	Saturation	S_0	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Before Shear	Water content	w_c	%	%	%	%
	Void ratio	e_c				
	Saturation	S_c	%	%	%	%
	Final back pressure, T/sq ft	u_0				
Final	Water content	w_f	%	%	%	%
	Void ratio	e_f				
Minor principal stress, T/sq ft Eff		$\bar{\sigma}_3$	0.21	0.90	1.09	1.37
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$				
Time to failure, min		t_f				
Rate of strain, percent/min						
Major Principal Stress, T/sq ft Eff		$\bar{\sigma}_1$	0.75	2.07	3.65	4.40
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$				
Initial diameter, in.		D_0				
Initial height, in.		H_0				

Shear Strength Parameters

φ' = 31.4°

tan φ' = 0.610

c' = 0 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Type of test $\bar{R}$ | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL Nat 127 OD 76 | PL Nat 51 OD 55 | PI Nat 76 OD 21 | D_{10} <0.001 | G_s 2.44

Remarks See Sheet 1 of 2 for

Project Delaware River Disposal Area Study

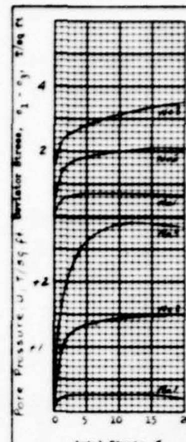
Area Oldmans No1 Disposal Area

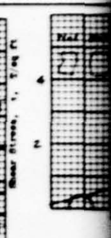
Boring No. EAB-4 | Sample No. UD-1

Depth 4.0'-6.0' | Date Oct 1967

Sheet 2 of 2

TRIAXIAL COMPRESSION TEST REPORT





Test No.

Initial: Water content; Void ratio; Saturation; Dry density, lb/cu ft

Before Shear: Water content; Void ratio; Saturation; Final back pressure, T/sq ft

Final: Water content; Void ratio

Minor principal stress, T/sq ft

Max deviator stress, T/sq ft

Time to failure,

Rate of strain, percent/min

Pore Pressure T/sq ft

Ult deviator stress, T/sq ft

Initial diameter

Initial height,

Shear Strength Parameters

φ = 15.9°

tan φ = 0.285

c = 0.10 T/sq ft

Method of saturation Backpressure

☐ Controlled stress

☒ Controlled strain

Type of test R | Type of specimen Undis…

Classification Organic CLAY (OH)

LL Nat 63 O.D. 52 | PL Nat 30 OD 29 | PI Nat 33

Remarks *Stress @ 15% Strain

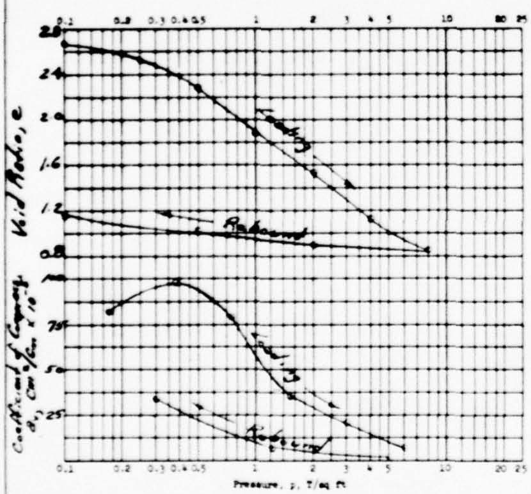
Project

Area Ol…

Boring

Depth

Sheet 1 of 2



Type of Specimen Undisturbed		Before Test		After Test	
Diam 3.0 in.	Ht 0.75 in.	Water Content, w_0	108.6 %	w_f	61.9 %
Overburden Pressure, p_0 0.20 T/sq ft		Void Ratio, e_0	2.771	e_f	1.146
Precons. Pressure, p_c 0.38 T/sq ft		Saturation, S_0	97.6 %	S_f	100+ %
Compression Index, C_c 1.26		Dry Density, γ_d	41.2 lb/ft³		
Classification Organic CLAY (OH)		k_{20} at e_0 = × 10⁻ cm/sec			
LL Nat 134 OD 75	G_s 2.47				
PL 47 53	D_{10} <0.001				

Remarks

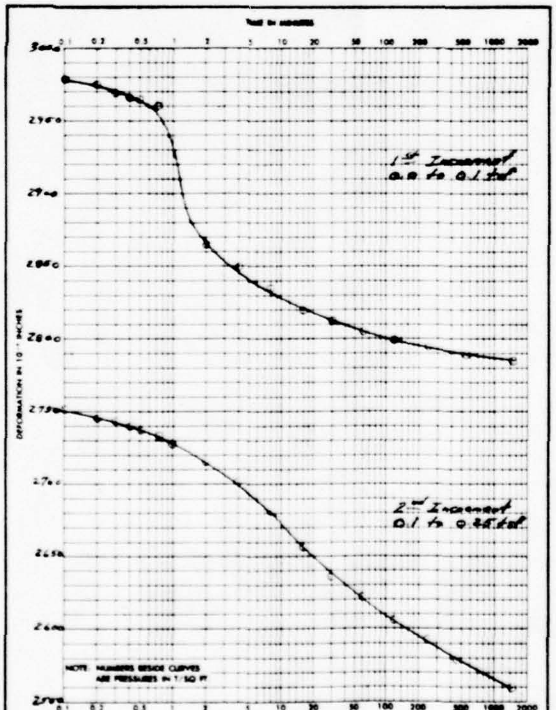
Project Long Range Delaware River Disposal Area

Area Oldmans No. 1

Boring No. EAB-1 | Sample No. UD-1

Depth 6.0'-8.0' | Date Oct. 1967

CONSOLIDATION TEST REPORT

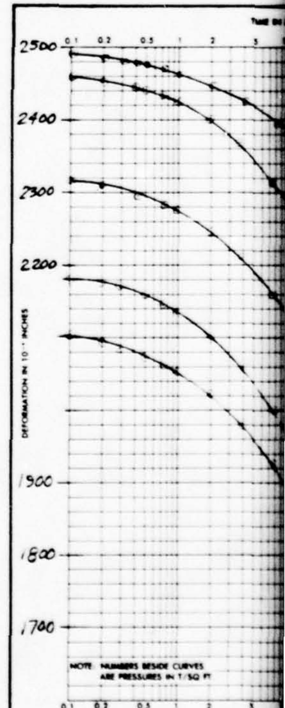


PROJECT Long Range Delaware River Disposal Area Study

AREA Oldmans No. 1

BORING NO. EAB-1 | SAMPLE NO. UD-1 | DEPTH 6.0-8.0 | DATE May '67

ENG FORM 2088, 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE — CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)

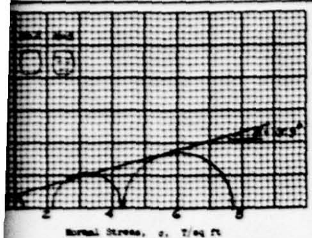


PROJECT Long Range Delawa…

AREA Oldmans No. 1

BORING NO. EAB-1 | SAMPLE NO. UD-1

ENG FORM 2088, 1 MAY 63 — PREVIOUS EDITIONS ARE OBSOLETE — CONSOLIDAT…



		1	2	3	
... content	w_o	42.1 %	49.2 %	43.2 %	%
... ratio	e_o	1.258	1.277	1.331	
... ation	S_o	87.3 %	88.3 %	84.6 %	%
... density, ... ft	γ_d	72.1	71.5	69.9	
... content	w_c	41.8 %	39.4 %	36.1 %	%
... ratio	e_c	1.091	1.029	0.962	
... ation	S_c	100 %	100 %	100 %	%
... back pressure, T/sq ft	u_o	7.20	7.20	7.20	
... content	w_f	41.8 %	39.4 %	36.1 %	%
... ratio	e_f	1.091	1.029	0.942	
... principal ... T/sq ft	σ_3	0.54	2.16	4.32	
... deviator ... T/sq ft $(\sigma_1-\sigma_3)_{max}$		0.71	2.09*	3.33*	
... failure, min	t_f	47.4	77.0	75.8	
... strain, ... /min		0.19	0.19	0.20	
... pressure ...	u	+0.27	+1.46*	+2.08*	
... deviator ... T/sq ft $(\sigma_1-\sigma_3)_{ult}$		0.72	—	—	
... diameter, in.	D_o	1.39	1.39	1.41	
... height, in.	H_o	3.14	3.15	3.15	

...Undisturbed

...(OH)

... Bot 39 U.D. 23 | D_{10} <0.001 | G_s 2.61

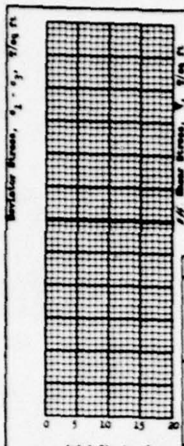
Project Delaware River Disposal Area Study

Area Oldmans No1 Disposal Area

Boring No. EAB-5 | Sample No. UD-2

Depth, ft. 13.0'-15.0' | Date Oct. 1967

TRIAXIAL COMPRESSION TEST REPORT



Shear Strength Parameters

$\bar{\phi}$ = 32.8°

tan $\bar{\phi}$ = 0.633

$\bar{c}$ = 0 T/sq ft

Method of saturation: Backpressure

☐ Controlled stress

☒ Controlled strain

Test No.			1	2	3	
Initial	Water content	w_o	%	%	%	%
	Void ratio	e_o				
	Saturation	S_o	%	%	%	%
	Dry density, lb/cu ft	γ_d				
Before Shear	Water content	w_c	%	%	%	%
	Void ratio	e_c				
	Saturation	S_c	%	%	%	%
	Final back pressure, T/sq ft	u_o				
Final	Water content	w_f	%	%	%	%
	Void ratio	e_f				
Minor principal stress, T/sq ft EH		$\bar{\sigma}_3$	0.27	0.70*	1.44*	
Max deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{max}$				
Time to failure, min		t_f				
Rate of strain, percent/min						
Major principal stress, T/sq ft EH		$\bar{\sigma}_1$	1.41	2.79*	4.83*	
Ult deviator stress, T/sq ft		$(\sigma_1-\sigma_3)_{ult}$				
Initial diameter, in.		D_o				
Initial height, in.		H_o				

Type of test R | Type of specimen Undisturbed

Classification Organic CLAY (OH)

LL Bot 63 U.D. 52 | PL Bot 30 U.D. 29 | PI Bot 33 U.D. 23 | D_{10} <0.001 | G_s 2.61

Remarks *Stress @ 15% Strain. see Sheet 1 of 2 for other data

Sheet 2 of 2

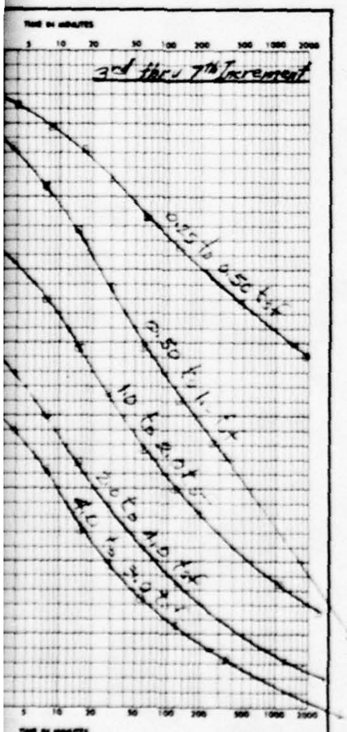
Project Delaware River Disposal Area Study

Area Oldman's No1 Disposal Area

Boring No. EAB-5 | Sample No. UD-3

Depth, ft. 13.0-15.0' | Date Oct 1967

TRIAXIAL COMPRESSION TEST REPORT



...aware River Disposal Area Study

...-1 | Depth 6.0'-20' | Date Nov. 1967

...OLIDATION TEST—TIME CURVES (TRANSLUCENT)

EAB-4 (UD-1) R TEST
EAB-5 (UD-2) R TEST
EAB-1 (UD-1) CONSOLIDATION TEST

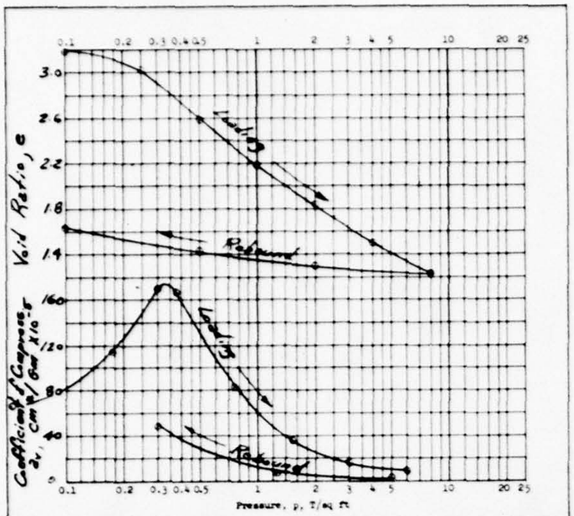
LONG RANGE SPOIL DISPOSAL STUDY

OLDMANS No.1 DISPOSAL AREA TEST REPORTS

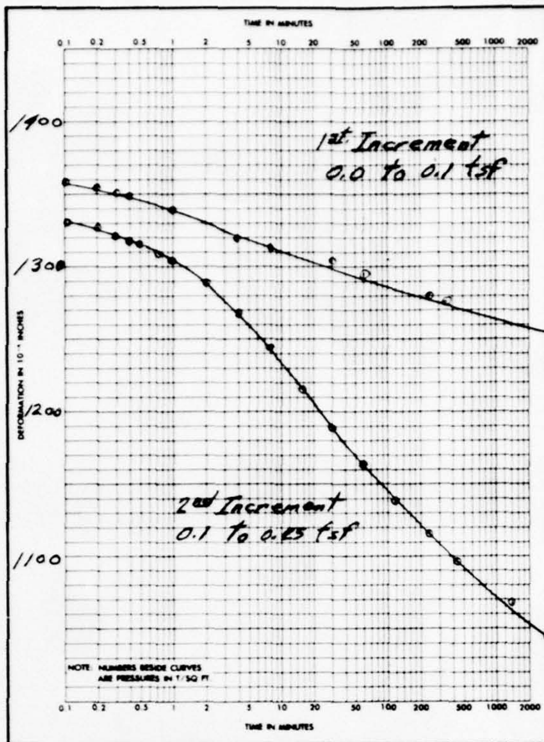
U. S. ARMY ENGINEER DISTRICT PHILADELPHIA

2

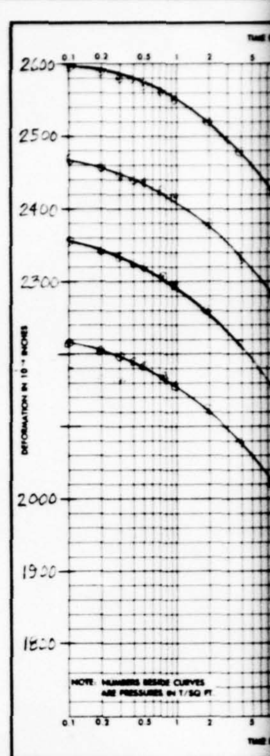
PLATE 34



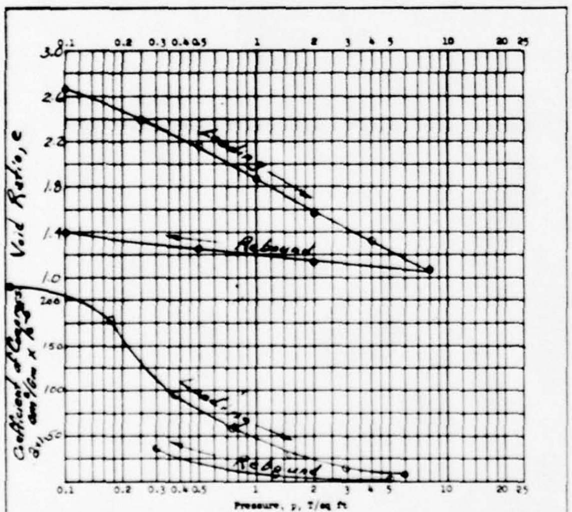
Type of Specimen Undisturbed		Before Test		After Test	
Diam 3.0 in.	Ht 0.75 in.	Water Content, w_o	127.2 %	w_f	68.1 %
Overburden Pressure, Po 0.23 T/sq ft		Void Ratio, e_o	3.254	e_f	1.616
Preconsol. Pressure, Pc 0.25 T/sq ft		Saturation, S_o	99.3 %	S_f	100+ %
Compression Index, C_c 1.16		Dry Density, γ_d	37.3 lb/ft³		
Classification Organic CLAY (OH) w/ decayed wood & veg		k_{20} at e_o =	$\times 10^{-}$ cm/sec		
LL Nat 115, OD 37	G_s 2.59	Project Long Range Delaware River Disposal Area			
PL 42, 30	D_{10} < 0.001				
Remarks Sample of the original ground.		Area Oldman's No. 1			
		Boring No. EAB-6		Sample No. UD-2	
		Depth 12.0' - 14.0'		Date Oct 1967	
		CONSOLIDATION TEST REPORT			



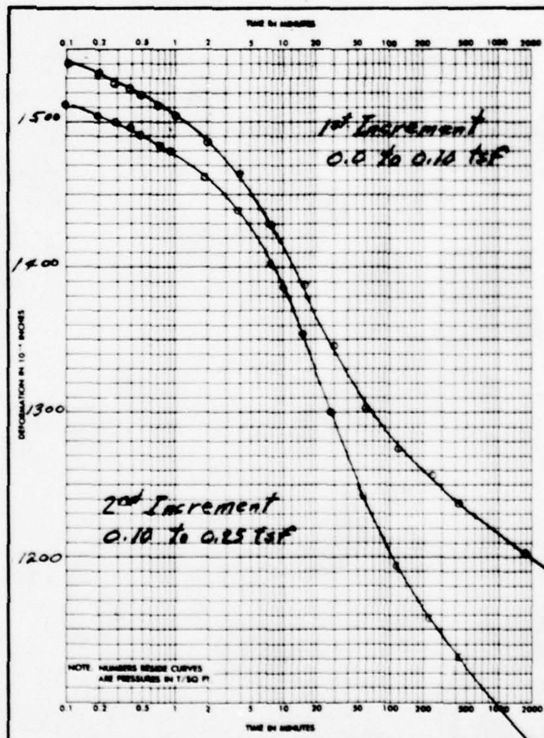
PROJECT Long Range Delaware River Disposal Area Study
AREA Oldmans No. 1
BORING NO EAB-6 SAMPLE NO UD-2 DEPTH 12.0-14.0 DATE Nov 1967
ENG FORM 2086 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



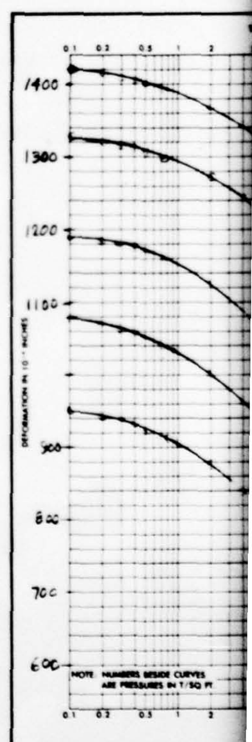
PROJECT Long Range Delaw
AREA Oldmans No. 1
BORING NO EAB-6 SAMPLE NO UD-2
ENG FORM 2086 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE CONSOLI



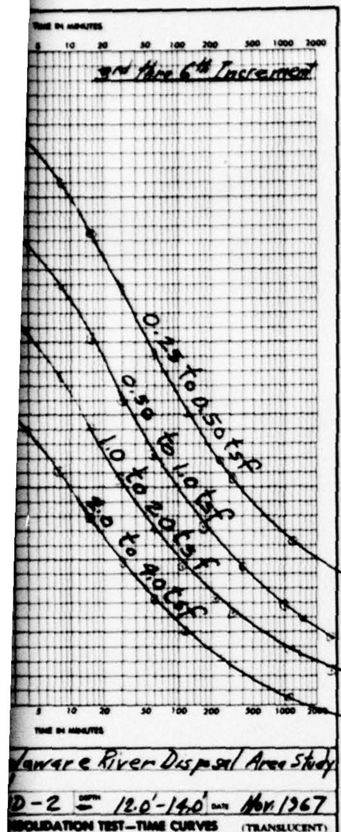
Type of Specimen Undisturbed		Before Test		After Test	
Diam 2.6 in.	Ht 0.75 in.	Water Content, w_o	114.7 %	w_f	62.8 %
Overburden Pressure, Po 0.16 T/sq ft		Void Ratio, e_o	2.877	e_f	1.400
Preconsol. Pressure, Pc 0.80 T/sq ft		Saturation, S_o	98.1 %	S_f	100+ %
Compression Index, C_c 0.70		Dry Density, γ_d	37.6 lb/ft³		
Classification Organic CLAY (OH) w/ ... material		k_{20} at e_o =	$\times 10^{-}$ cm/sec		
LL Nat 147, OD 78	G_s 2.46	Project Long Range Delaware River Disposal Area			
PL 54, 40	D_{10} < 0.001				
Remarks		Area Oldman's No. 1			
		Boring No. EAB-3		Sample No. UD-1	
		Depth 8.0 - 10.0		Date Oct 1967	
		CONSOLIDATION TEST REPORT			

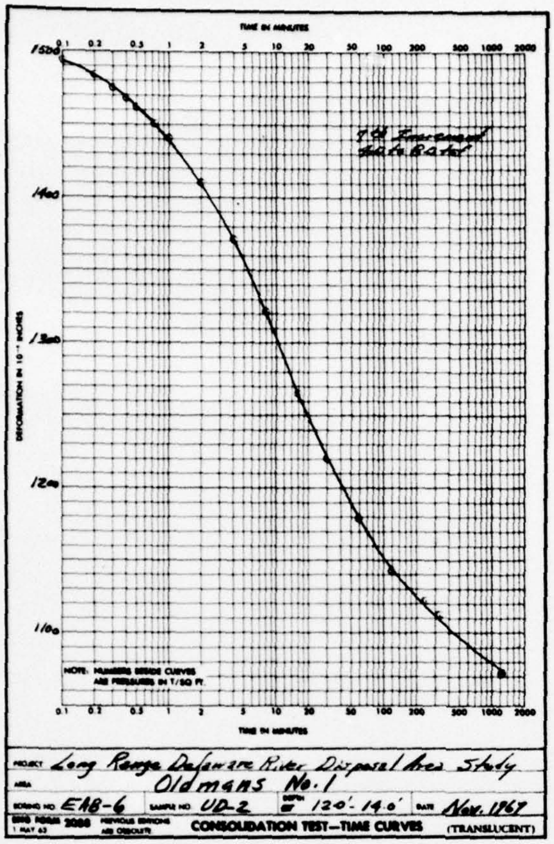


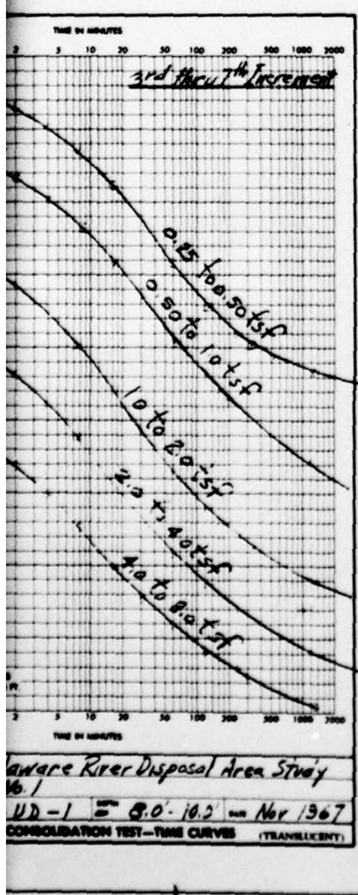
PROJECT Long Range Delaware River Disposal Area Study
AREA Oldmans No. 1
BORING NO EAB-3 SAMPLE NO UD-1 DEPTH 8.0-10.0 DATE Nov 1967
ENG FORM 2086 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



PROJECT Long Range Delaw
AREA Oldmans No. 1
BORING NO EAB-3 SAMPLE NO UD
ENG FORM 2086 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE CONS







CONSOLIDATION TEST FOR:
EAB-6(UD-2)
EAB-3(UD-1)

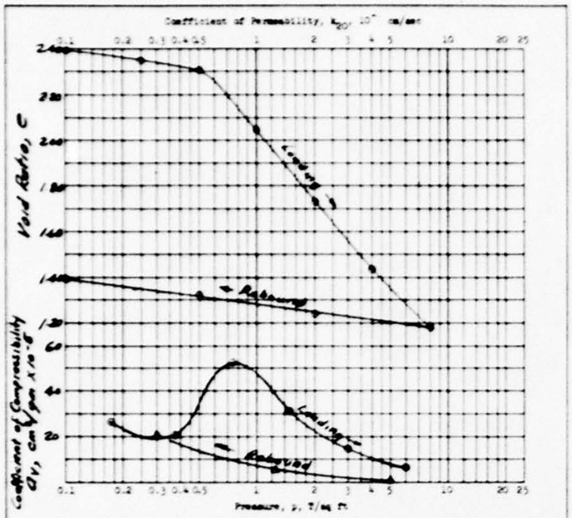
LONG RANGE SPOIL DISPOSAL STUDY

OLDMANS No.1 DISPOSAL AREA TEST REPORTS

U. S. ARMY ENGINEER DISTRICT PHILADELPHIA

2

PLATE 35



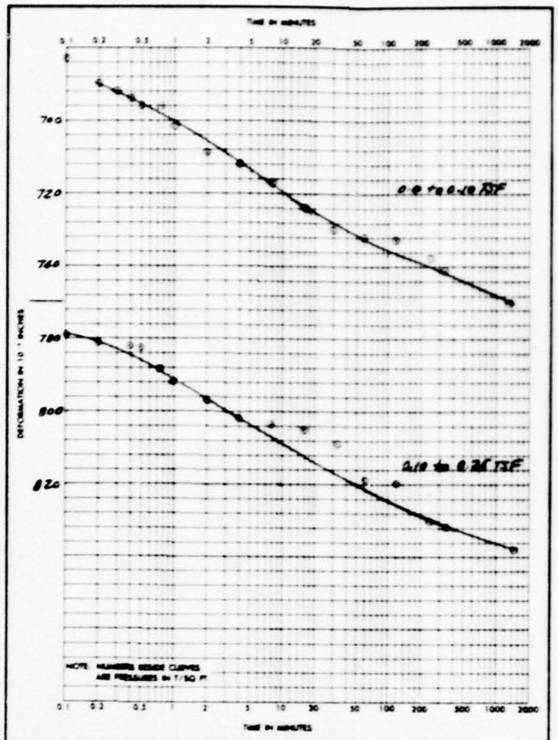
Type of Specimen: Undisturbed	Before Test		After Test	
Diam 3.0 in. Ht 0.75 in.	Water Content, w_0	96.0 %	w_f	61.7 %
Overburden Pressure, p_0 0.67 T/sq ft	Void Ratio, e_0	2.489	e_f	1.553
Precompl. Pressure, p_c 0.60 T/sq ft	Saturation, S_0	99.1 %	S_f	100 %
Compression Index, C_c 0.981	Dry Density, γ_d	45.7 lb/ft³		
Classification: Dark gray organic silty CLAY (OH)	k_{20} at e_0 =	× 10^{-} cm/sec		

LL Nat 118, Air 71; G_s 2.52
PL Nat 72, Air 53; D_{10} <0.001

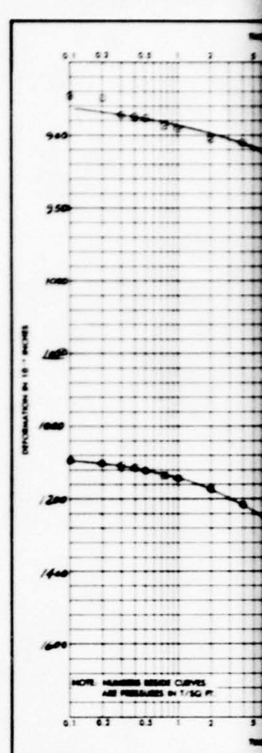
Project: Long Range Delaware River Disposal Area Study
Area: Pigeon Point, Delaware
Boring No. DFB-60 Sample No. UD-3
Depth, ft 26.0'-28.0 Date Feb 1968

Remarks: Sample of the original ground.

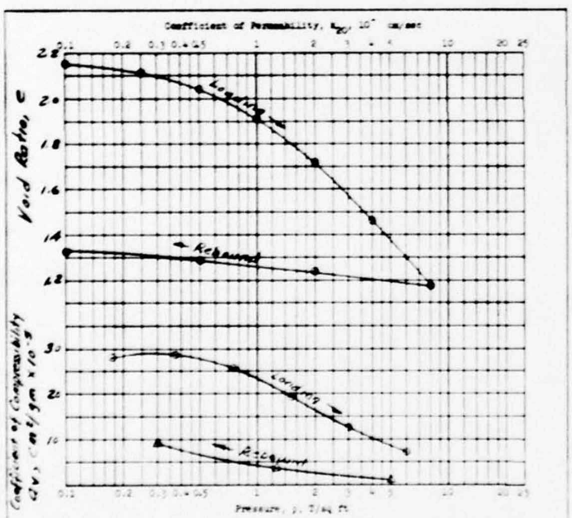
CONSOLIDATION TEST REPORT



Project: Long Range Delaware River Disposal Area Study
Area: Pigeon Point, Delaware
Boring No. DFB-60 Sample No. UD-3 Depth 26.0'-28.0 Date Feb 1968
ENG FORM 2088 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



Project: Long Range Delaware
Area: Pigeon Point, Delaware
Boring No. DFB-60 Sample No. UD-3
ENG FORM 2088 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE CONSOLI



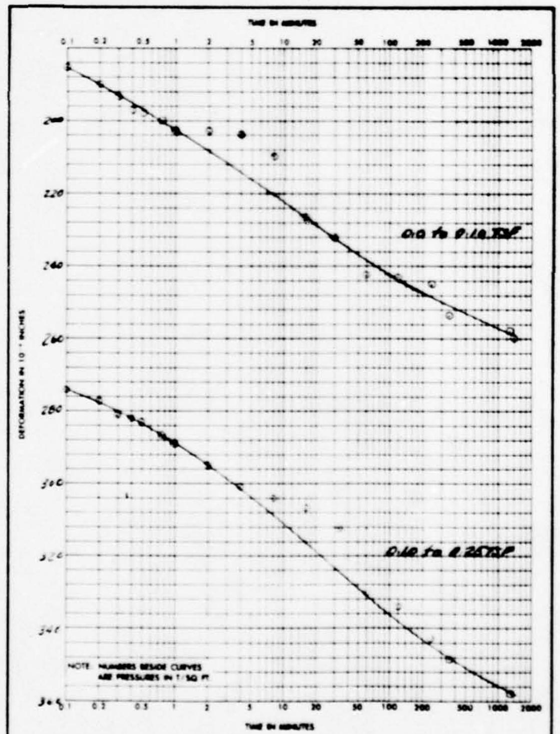
Type of Specimen: Undisturbed	Before Test		After Test	
Diam 3.0 in. Ht 0.75 in.	Water Content, w_0	79.0 %	w_f	55.6 %
Overburden Pressure, p_0 0.33 T/sq ft	Void Ratio, e_0	2.195	e_f	1.375
Precompl. Pressure, p_c 0.70 T/sq ft	Saturation, S_0	92.4 %	S_f	100 %
Compression Index, C_c 0.7?5	Dry Density, γ_d	50.1 lb/ft³		
Classification: Dark gray organic clayey silt (OH)	k_{20} at e_0 =	× 10^{-} cm/sec		

LL Nat 94, Air 65; G_s 2.57
PL Nat 46, Air 46; D_{10} <0.001

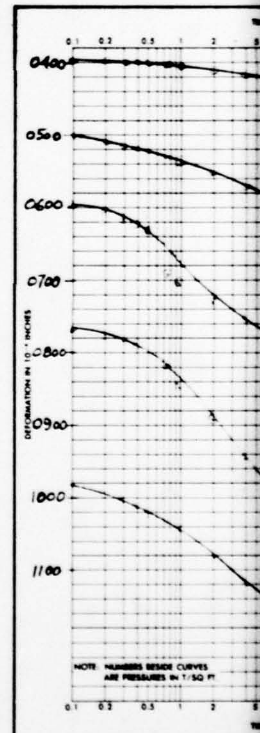
Project: Long Range Delaware River Disposal Area Study
Area: Pigeon Point, Delaware
Boring No. DFB-60 Sample No. UD-1
Depth, ft 6.0'-6.0' Date Feb 1968

Remarks:

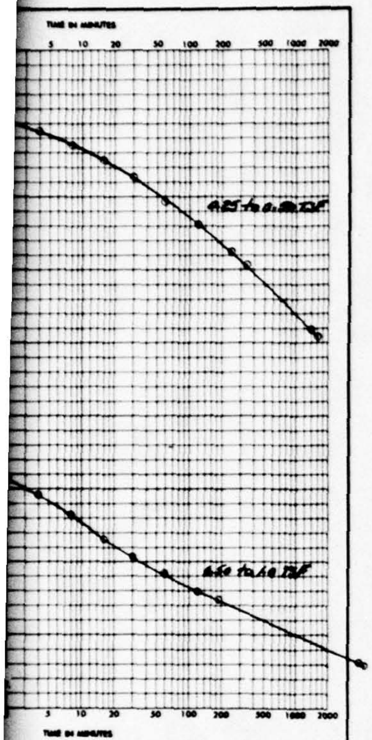
CONSOLIDATION TEST REPORT



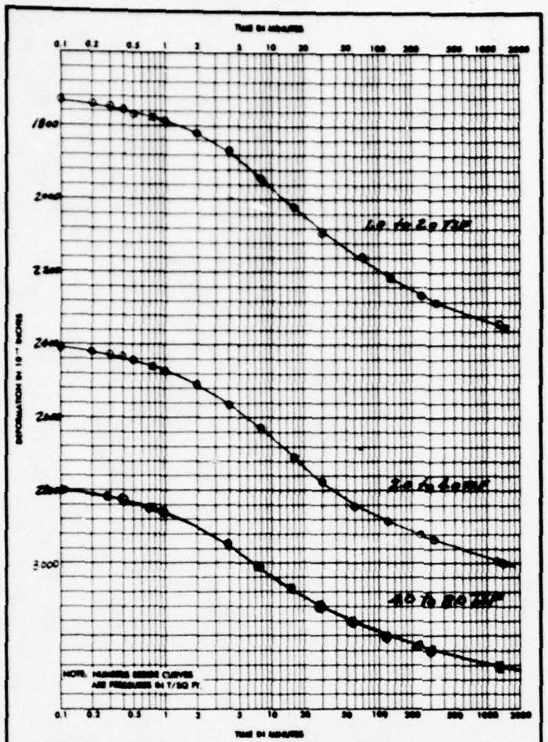
Project: Long Range Delaware River Disposal Area Study
Area: Pigeon Point, Delaware
Boring No. DFB-60 Sample No. UD-1 Depth 6.0'-6.0' Date Feb 1968
ENG FORM 2088 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



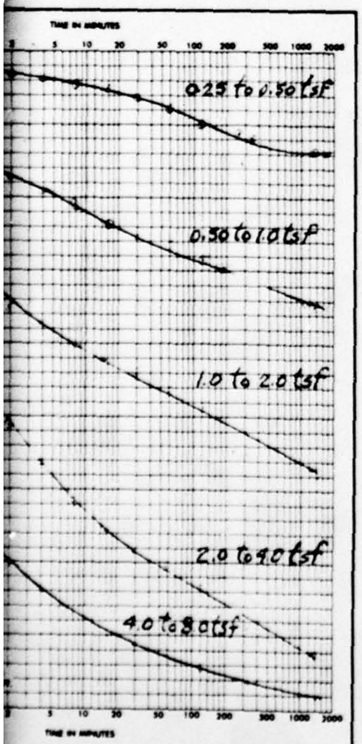
Project: Long Range Delaware
Area: Pigeon Point, De[illegible]
Boring No. DFB-60 Sample No. UD-1
ENG FORM 2088 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE CONSOL



...ware River Disposal Area Study
...elaware
UD-3 | DEPTH 26.0'-28.0' | DATE Feb.1968
...NSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



PROJECT Long Range Delaware River Disposal Area Study
AREA Pigeon Point, Delaware
BORING NO. DFB-60 | SAMPLE NO. UD-3 | DEPTH 26.0'-28.0' | DATE Feb.1968
ENG FORM 2088, 1 MAY 63 | PREVIOUS EDITIONS ARE OBSOLETE | CONSOLIDATION TEST—TIME CURVES (TRANSLUCENT)



...ware River Disposal Area Study
... Delaware
UD-1 | DEPTH 60-80 | DATE Feb.1968
...NSOLIDATION TEST—TIME CURVES (TRANSLUCENT)

CONSOLIDATION TEST FOR:
DFB-60 (UD-1,3)

LONG RANGE SPOIL DISPOSAL STUDY

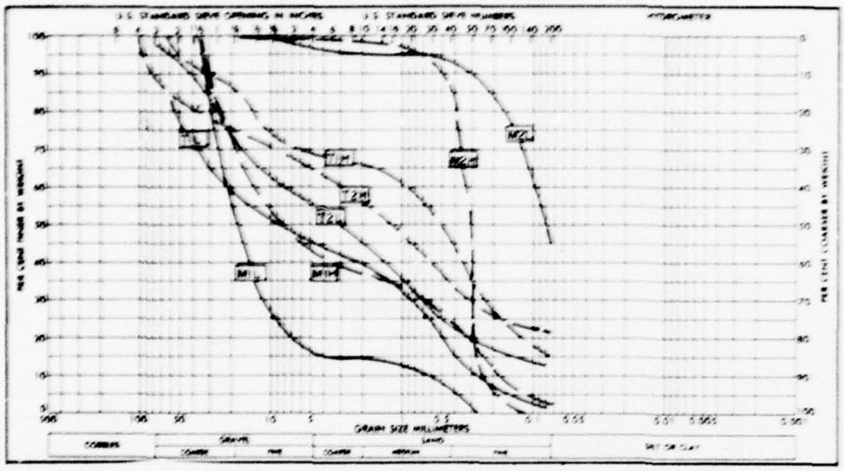
PIGEON POINT DISPOSAL AREA TEST REPORTS

U. S. ARMY ENGINEER DISTRICT PHILADELPHIA

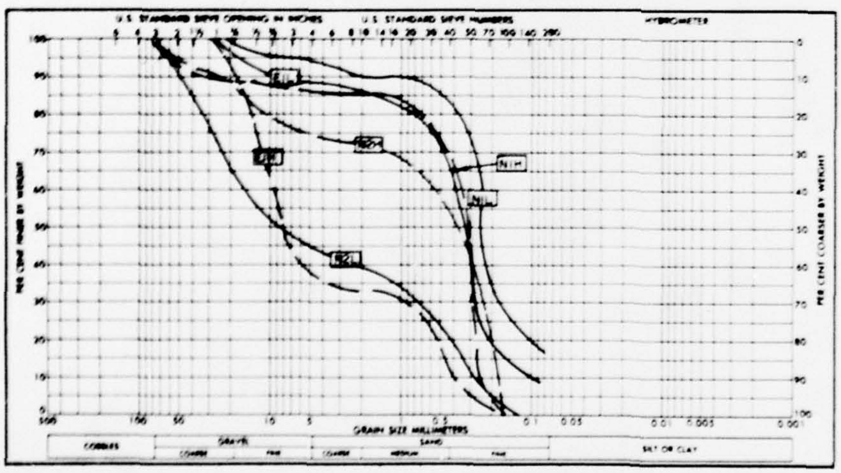
2

PLATE 36

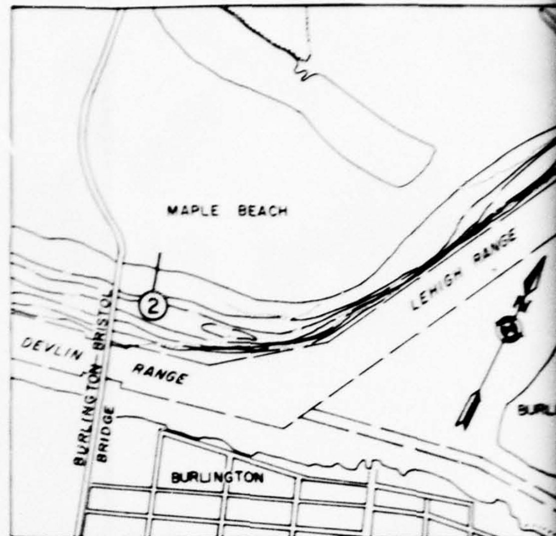
1



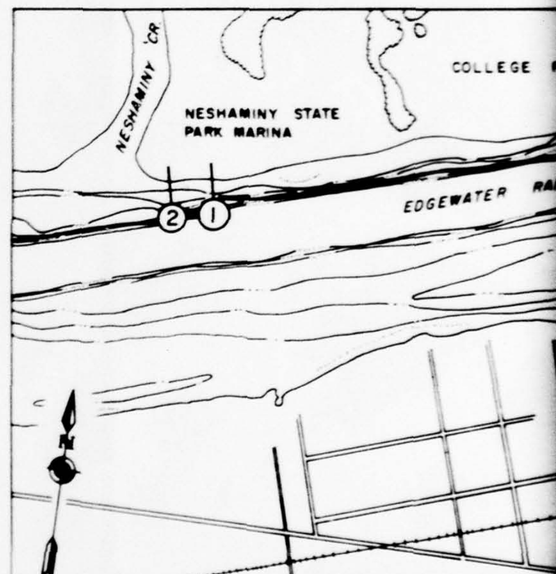
CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	BEACH SLOPE	ELEVATION		
				SAMPLE	MLW	MHW
T1L	N.J.-PA. T/P BRIDGE LINE NO. 1	2FB	8.3 to 1	-0.4	+0.3	+6.8
T1H	" " " " " " "	1FB	"	+5.4	"	"
T2L	" " " " LINE NO. 2	3FB	6.8 to 1	0.0	"	"
T2H	" " " " " " "	4FB	"	+5.1	"	"
M1L	MAPLE BEACH LINE NO. 1	1BB	7.5 to 1	0.0	+0.2	+6.6
M1H	" " " " "	2BB	"	+5.6	"	"
M2L	" " LINE NO. 2	3BB	13.4 to 1	0.0	"	"
M2H	" " " " "	4BB	"	+5.6	"	"



CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	BEACH SLOPE	ELEVATION		
				SAMPLE	MLW	MHW
N1L	NESHAMINY ST. PK. LINE NO. 1	2NP	7.3 to 1	+0.5	+0.2	+6.5
N1H	" " " " " "	1NP	"	+7.1	"	"
N2L	" " " LINE NO. 2	4NP	8.9 to 1	0.0	"	"
N2H	" " " " " "	3NP	"	+6.7	"	"
E1L	EDGEWATER PARK LINE NO. 1	1EP	7.0 to 1	0.0	"	"
E1H	" " " " "	2EP	"	+6.6	"	"



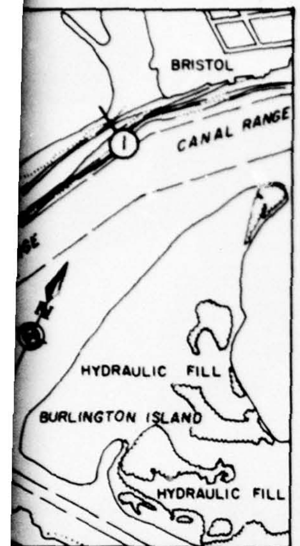
LOCATION PLAN
MAPLE BEACH

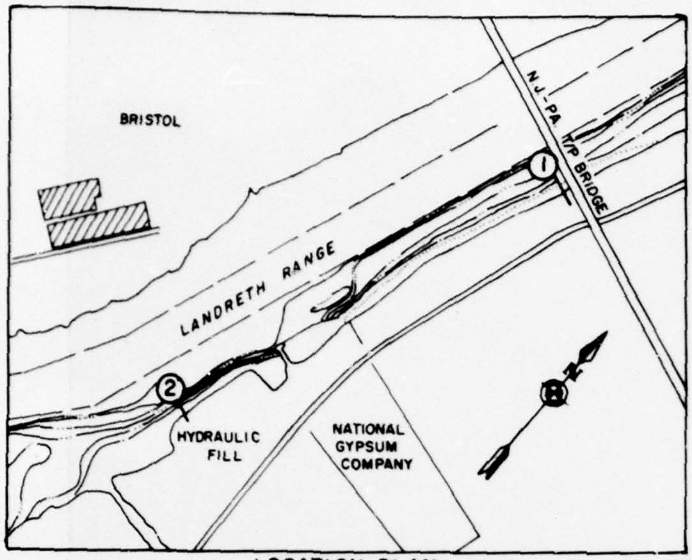


LOCATION PLAN
EDGEWATER PARK - NESHAMINY STATE

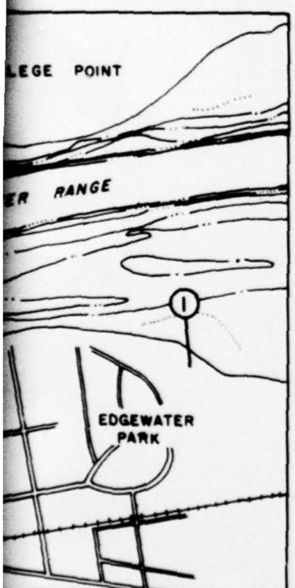
SCALE IN FEET
800 0 800 1600

1





LOCATION PLAN
N.J.-PA. T/P BRIDGE



STATE PARK

1600

NOTES:

1. DEPTH CURVES ARE BASED ON SOUNDINGS MADE WITH A DEPTHFINDER AND ARE SHOWN AS FEET BELOW, CORPS OF ENGINEERS DELAWARE RIVER DATUMS.
   0 FEET CURVE OF DEPTH SHOWN THUS
   6 " " " " " "
   12 " " " " " "
   18 " " " " " "
   24 " " " " " "
   30 " " " " " "
   36 " " " " " "
2. LOCATION OF PROFILE & SAMPLING LINE ARE SHOWN THUS —(2)
3. THE DELAWARE RIVER PHILADELPHIA TO TRENTON PROJECT DATUM(2.401 FEET BELOW U.S.C. & G.S. SEA LEVEL DATUM 1929) IS THE APPLICABLE DATUM FOR THE FOLLOWING LOCATION PLANS.
   PLATE 1 MAPLE BEACH, EDGEWATER PARK, NESHAMINY STATE PARK & N.J.-PA. T/P BRIDGE
   PLATE 2 WRIGHT COVE, WRIGHT POINT, KAISER GYPSUM
4. THE DELAWARE RIVER DATUM (2.901 BELOW U.S.C. & G.S. SEA LEVEL DATUM 1929) IS THE DATUM FOR THE FOLLOWING LOCATION PLANS,
   PLATE 2 NATIONAL PARK & EAGLE POINT
   PLATE 3 MANTUA CREEK, TINICUM ISLAND
   PLATE 4 PENNSVILLE, WESTINGHOUSE-LESTER, FORT MOTT, OAKWOOD BEACH & ELSINBORO POINT.

LONG RANGE SPOIL DISPOSAL STUDY

DESIGN OF DIKING IN WATER
DELAWARE RIVER BEACHES
LOCATION PLANS & GRADATION CURVES

U.S.ARMY ENGINEER DISTRICT
PHILADELPHIA

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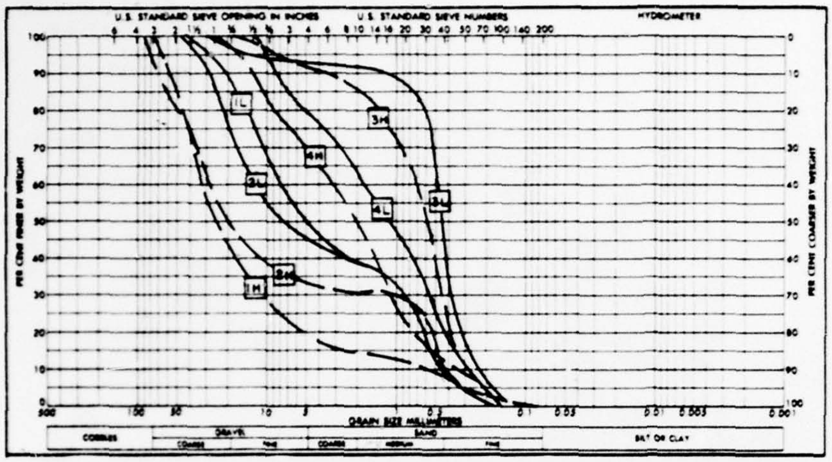
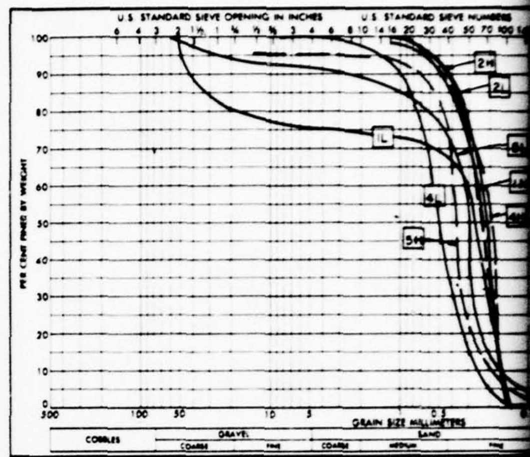
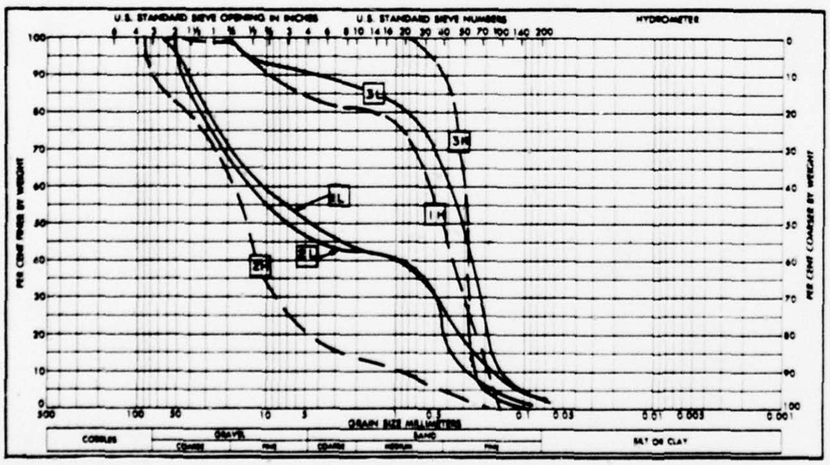


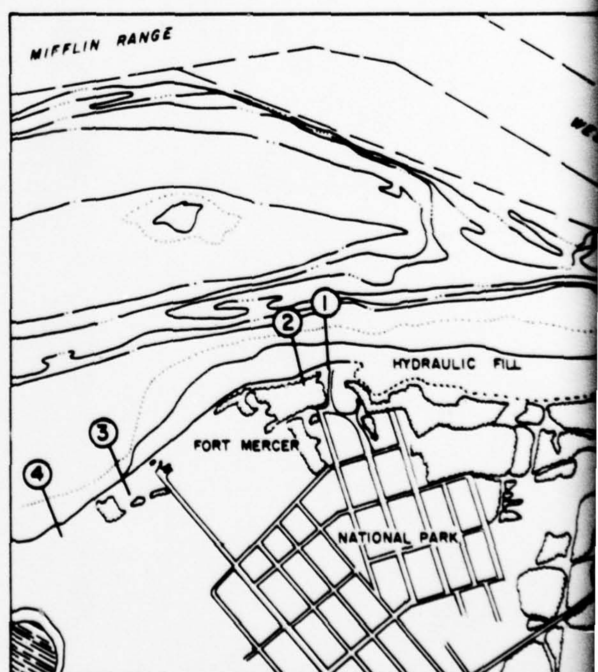
CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	BEACH SLOPE	ELEVATION		
				SAMPLE	MLW	MHW
1L	NATIONAL PARK LINE NO. 1	2NT	5.3 to 1	− 0.1	+ 0.7	+ 6.2
1H	" " " " "	1NT	"	+ 6.1	"	"
2L	" " LINE NO. 2	4NT	9.1 to 1	0.0	"	"
2H	" " " " "	3NT	"	+ 6.2	"	"
3L	" " LINE NO. 3	6NT	19.3 to 1	− 0.3	"	"
3H	" " " " "	5NT	"	+ 5.9	"	"
4L	" " LINE NO. 4	8NT	8.9 to 1	+ 1.2	"	"
4H	" " " " "	7NT	"	+ 6.0	"	"



CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	B S
4L	WRIGHT COVE LINE NO. 4	7WP	14
4H	" " " " "	8WP	
5L	" " LINE NO. 5	9WP	20.
5H	" " " " "	10WP	
1L	KAISER-GYPSUM LINE NO. 1	2KG	27.
1H	" " " " "	1KG	
2L	" " LINE NO. 2	4KG	25.
2H	" " " " "	3KG	

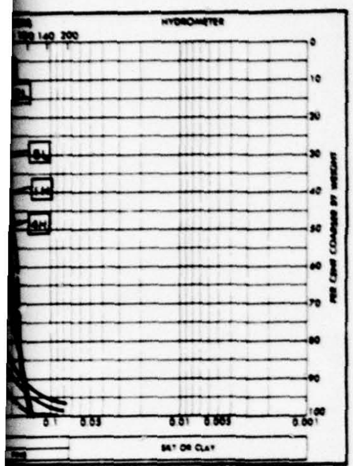


CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	BEACH SLOPE	ELEVATION		
				SAMPLE	MLW	MHW
1L	WRIGHT POINT LINE NO. 1	1WP	5.6 to 1	−0.6	+ 0.1	+ 6.5
1H	" " " " "	2WP	"	+3.4	"	"
2L	" " LINE NO. 2	3WP	9.0 to 1	−0.4	"	"
2H	" " " " "	4WP	"	+5.1	"	"
3L	WRIGHT COVE LINE NO. 3	5WP	14.1 to 1	0.0	"	"
3H	" " " " "	6WP	"	+6.0	"	"

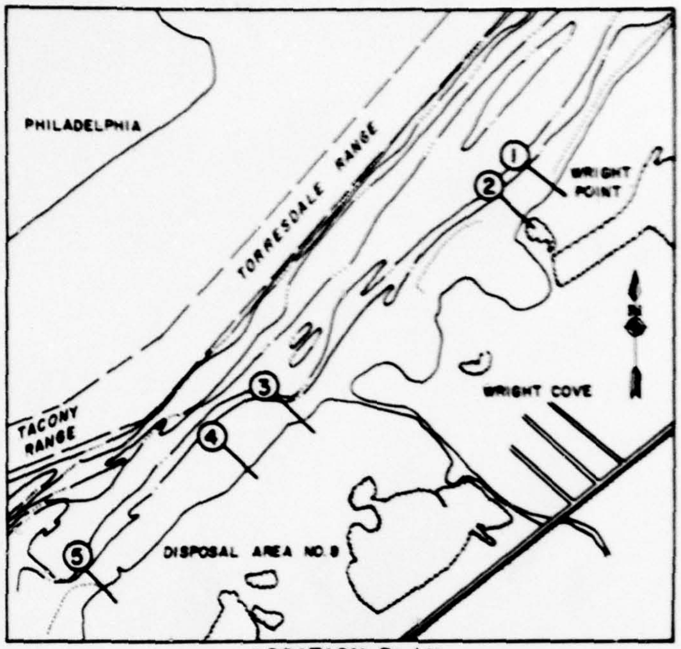


LOCATION PLAN
NATIONAL PARK & EA

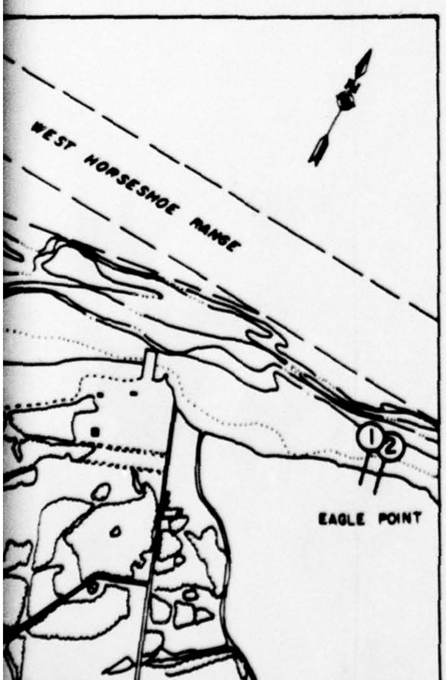
1



BEACH SLOPE	ELEVATION SAMPLE	ELEVATION MLW	ELEVATION MHW
14.4 to 1	0.0	+ 0.1	+ 6.5
"	+ 5.5	"	"
20.0 to 1	0.0	"	"
"	+ 5.9	"	"
27.8 to 1	+ 0.1	+ 0.1	+ 6.4
"	+ 6.5	"	"
25.7 to 1	- 0.1	"	"
"	+ 5.7	"	"

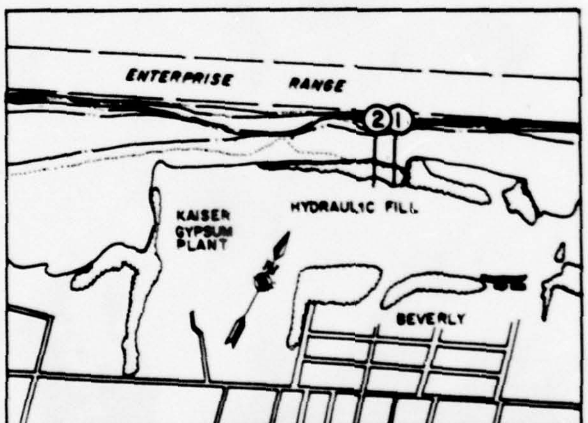


LOCATION PLAN
WRIGHT COVE & WRIGHT POINT



PLAN
EAGLE POINT

NOTE: GRADATION CURVES FOR EAGLE POINT SAMPLES SHOWN ON PLATE NO. 3



LOCATION PLAN
KAISER GYPSUM - BEVERLY

SCALE IN FEET
800 0 800 1600

FOR NOTES SEE PLATE 1

LONG RANGE SPOIL DISPOSAL STUDY
DESIGN OF DIKING IN WATER
DELAWARE RIVER BEACHES
LOCATION PLANS & GRADATION CURVES
U.S. ARMY ENGINEER DISTRICT
PHILADELPHIA

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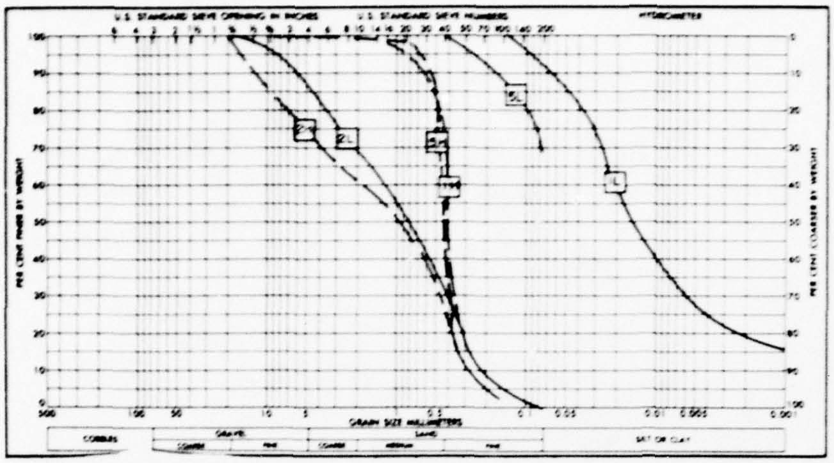
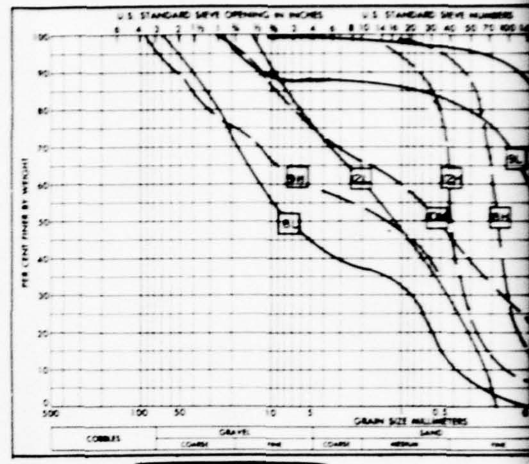
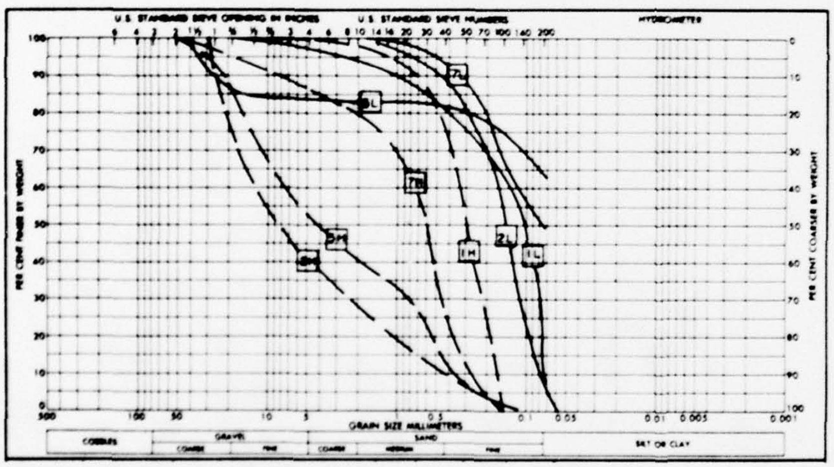


CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	BEACH SLOPE	ELEVATION		
				SAMPLE	MLW	MHW
1L	TINICUM ISLAND LINE NO 1	2TI	39.0 to 1	+ 6.3	+ 0.7	+ 6.1
1H	" " " " "	1TI	"	- 0.2	"	"
2L	" " LINE NO 2	3TI	41.0 to 1	+ 6.3	"	"
2H	" " " " "	4TI	"	0.0	"	"
5L	WESTINGHOUSE - LESTER LINE NO 5	9WL	52.0 to 1	- 0.1	"	"
5H	" " " "	10WL	"	+ 6.4	"	"

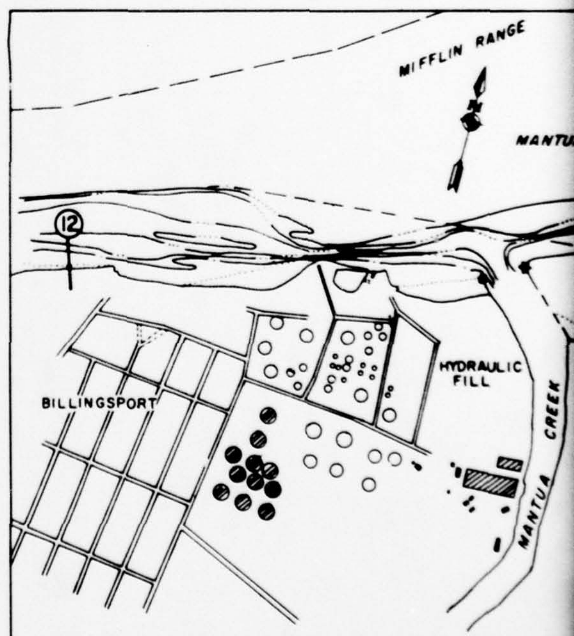


CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	B
			S
8L	MANTUA CREEK LINE NO 8	16MC	24.
8H	" " " " "	15MC	
9L	" " LINE NO 9	17MC	8.
9H	" " " " "	18MC	
10L	" " LINE NO 10	19MC	12.4
10H	" " " " "	20MC	
12L	" " LINE NO 12	23MC	8.
12H	" " " " "	24MC	



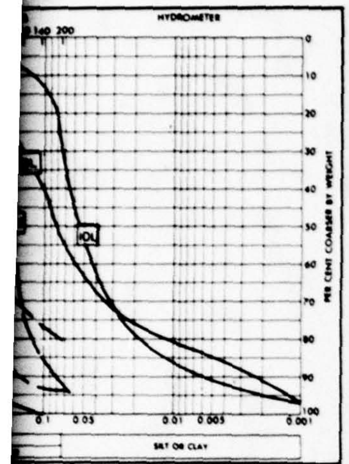
CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	BEACH SLOPE	ELEVATION		
				SAMPLE	MLW	MHW
1L	EAGLE POINT LINE NO 1	2AG	12.0 to 1	+ 0.2	+ 0.7	+ 6.2
1H	" " " " "	1AG	"	+ 6.5	"	"
2L	" " LINE NO 2	4AG	12.4 to 1	+ 0.2	"	"
2H	" " " " "	3AG	"	+ 6.1	"	"
5L	MANTUA CREEK LINE NO 5	9MC	12.2 to 1	- 0.2	+ 0.7	+ 6.1
5H	" " " " "	10MC	"	+ 7.2	"	"
7L	" " LINE NO 7	13MC	26.8 to 1	+ 0.3	"	"
7H	" " " "	14MC	"	+ 7.1	"	"

NOTE: EAGLE PT. SAMPLES TAKEN FROM BEACH AREA PROTECTED BY STONE ARMOR, HIGH WATER SAMPLES FROM LINE NO. 2 (CURVE 2H) TAKEN FROM STONE PROTECTION. LOCATION OF SAMPLING LINES FOR EAGLE POINT SAMPLES SHOWN ON PLATE NO. 2

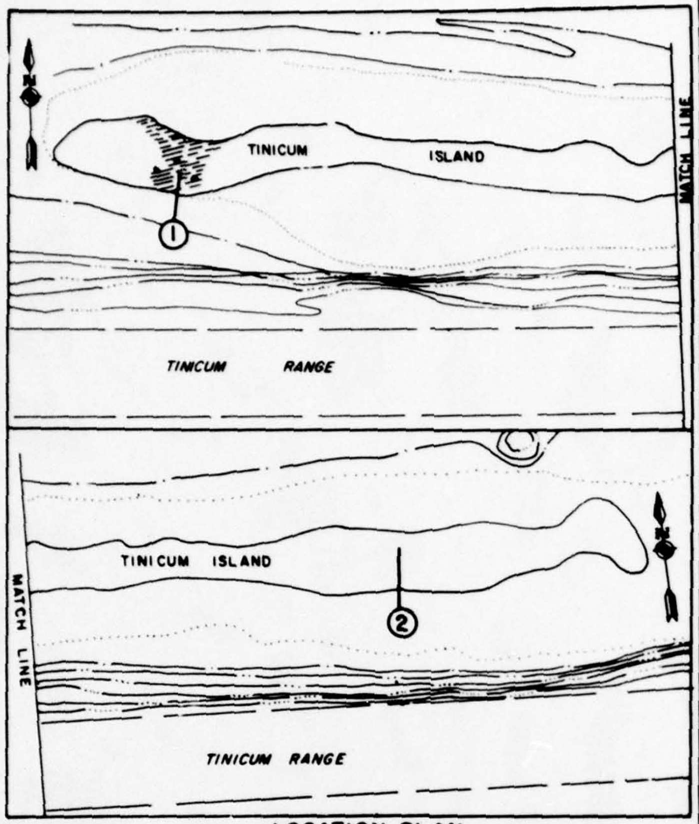


LOCATION PL
MANTUA CRE

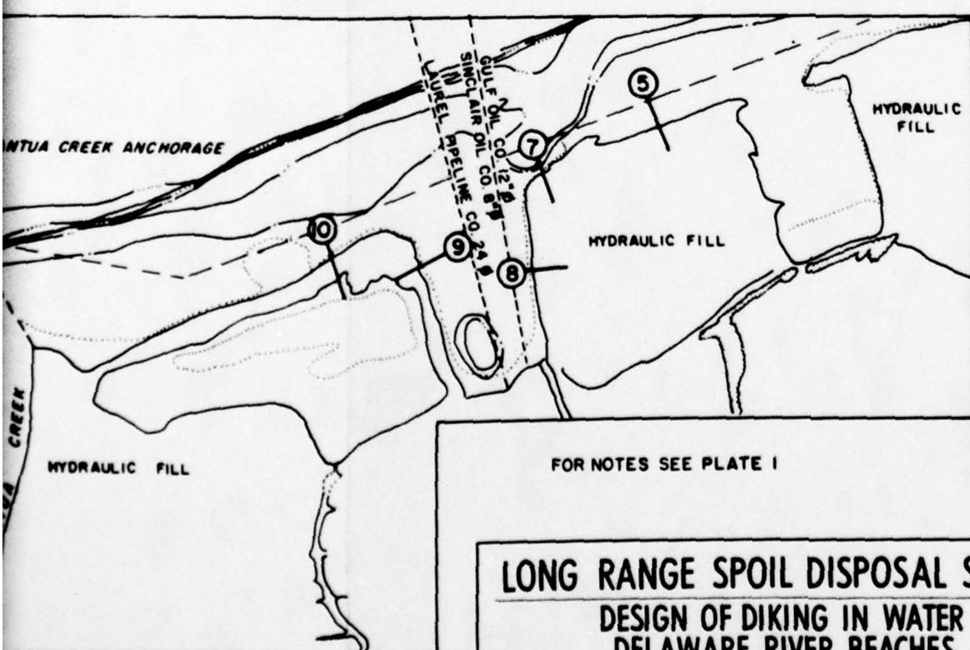
SCALE IN FEET
800 0 800 1600



BEACH SLOPE	ELEVATION		
	SAMPLE	MLW	MHW
24.1 to 1	+ 2.5	+ 0.7	+ 6.1
"	+ 8.8	"	"
8.1 to 1	- 0.1	"	"
"	+ 6.0	"	"
12.4 to 1	- 0.1	"	"
"	+ 6.5	"	"
8.2 to 1	- 0.1	"	"
"	+ 6.8	"	"



LOCATION PLAN
TINICUM ISLAND



PLAN
REEK

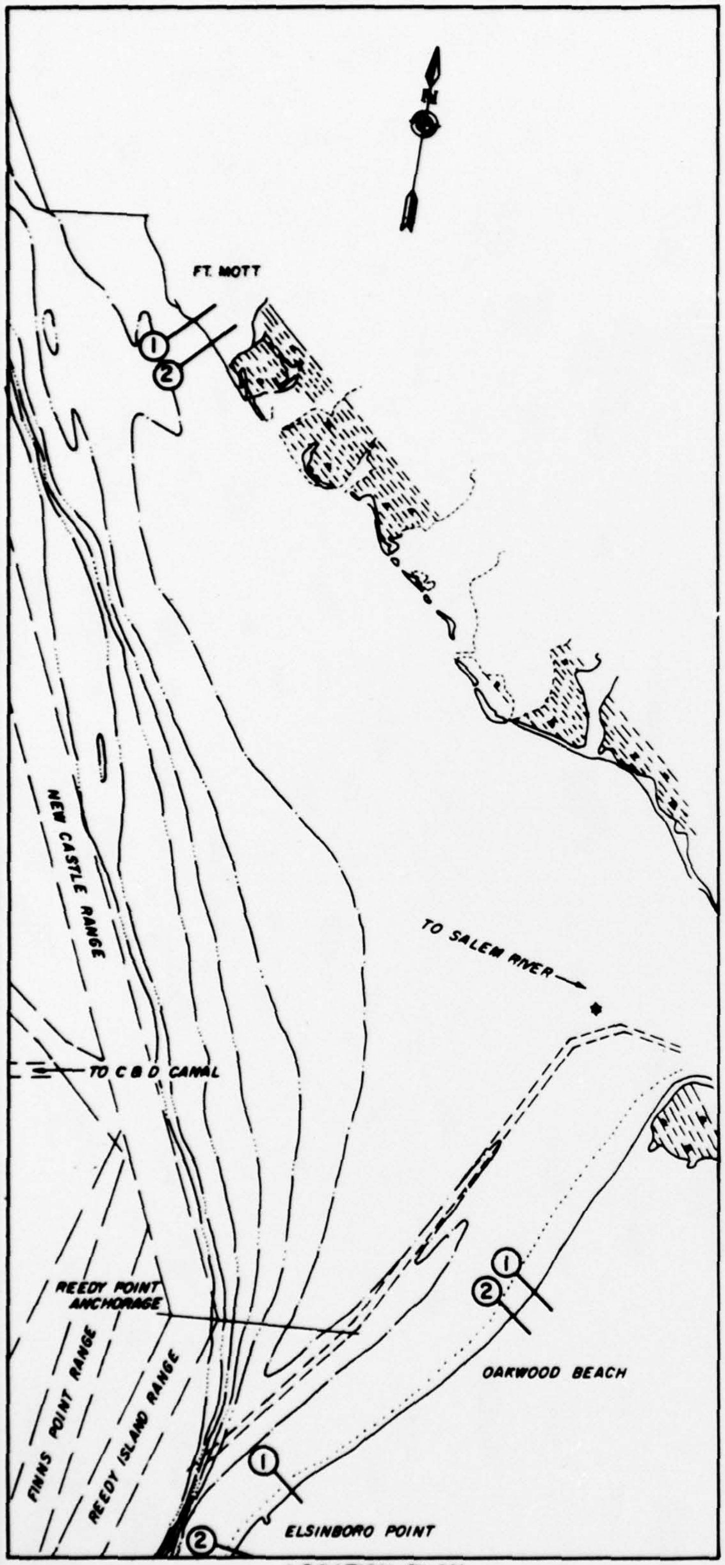
FOR NOTES SEE PLATE 1

LONG RANGE SPOIL DISPOSAL STUDY

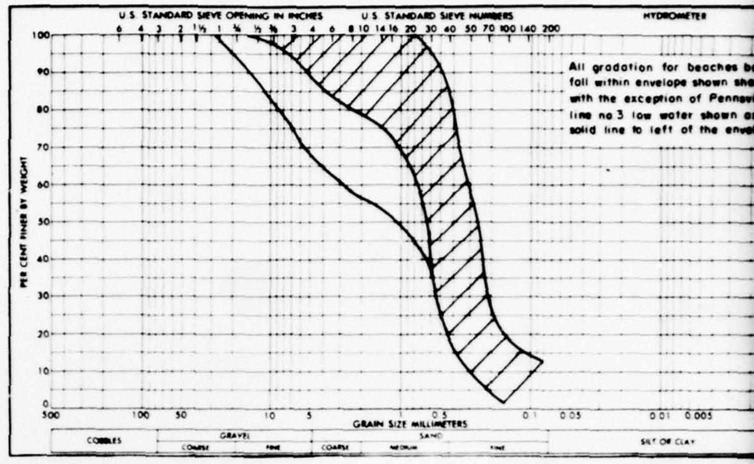
DESIGN OF DIKING IN WATER
DELAWARE RIVER BEACHES
LOCATION PLANS & GRADATION CURVES

U.S.ARMY ENGINEER DISTRICT
PHILADELPHIA

2

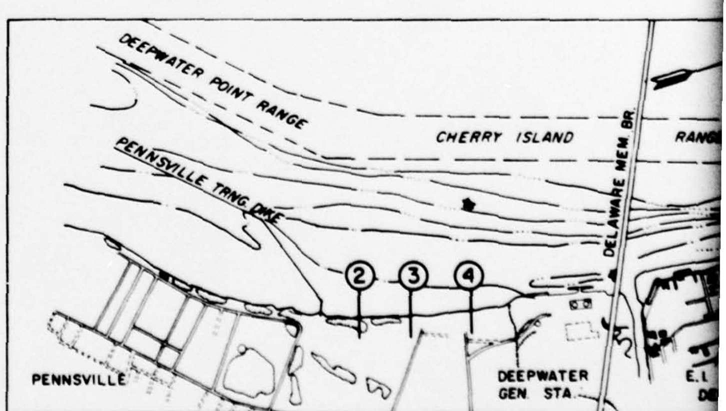


LOCATION PLAN
ELSINBORO PT. OAKWOOD BEACH & FT. MOTT
SCALE IN FEET 1600 0 1600 3200



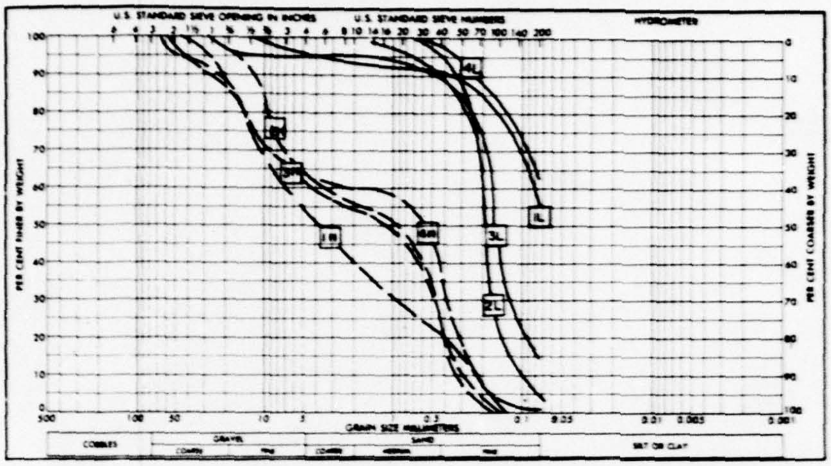
CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	BEACH SLOPE	ELEVATIO	
				SAMPLE	MLW
—	OAKWOOD BEACH - LINE NO. 1	20B	5.5 to 1	+ 0.1	+ 0.6
—	" " " " "	10 B	"	+ 6.8	"
—	" " LINE NO. 2 "	40B	4.3 to 1	+ 0.1	"
—	" " " " " "	30 B	"	+ 4.7	"
—	ELSINBORO POINT LINE NO. 1	2EL	7.4 to 1	0.0	"
—	" " " " "	1EL	"	+ 6.1	"
—	" " LINE NO. 2	4EL	17.2 to 1	- 0.1	"
—	" " " " "	3EL	"	+ 6.2	"
—	FT. MOTT LINE NO. 1	2FM	9.4 to 1	0.0	"
—	" " " " "	1FM	"	+ 5.8	"
—	" " LINE NO. 2	4FM	10 to 1	0.0	"
—	" " " " "	3FM	"	+ 6.0	"
—	PENNSVILLE LINE NO. 2	2PD	11.0 to 1	- 0.1	+ 0.6
—	" " " "	1 PD	"	+ 6.4	"
—	" LINE NO. 3	4PD	9.8 to 1	- 0.2	"
—	" "	3PD	"	+ 6.0	"
—	" LINE NO. 4	6PD	19.6 to 1	+ 0.3	"
—	" " " "	5PD	"	+ 6.4	"

* PROFILE INDICATES ACTIVE EROSION

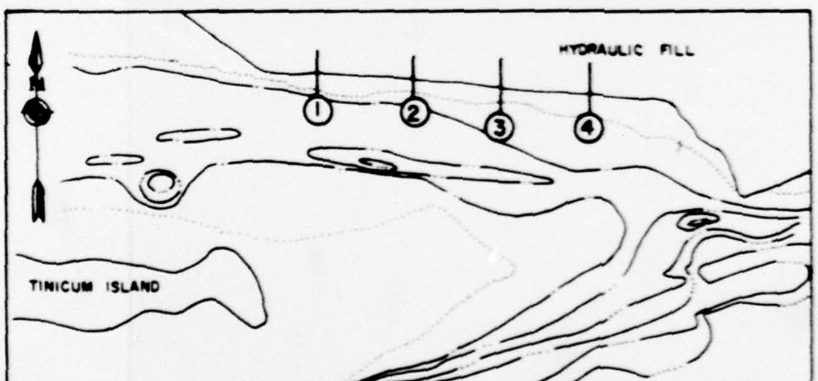


SCALE IN FEET
1600 0 1600 3200

LOCATION PLAN
PENNSVILLE



CURVE DESIGNATION	LOCATION	SAMPLE NUMBER	BEACH SLOPE	ELEVATION		
				SAMPLE	MLW	MHW
1L	WESTINGHOUSE - LESTER LINE NO.1	1WL	24.4 to 1	-0.3	+0.7	+6.1
1H	" " " " "	2WL	"	+6.0	"	"
2L	" " LINE NO.2	3WL	19.6 to 1	0.0	"	"
2H	" " " " "	4WL	"	+6.4	"	"
3L	" " LINE NO.3	5WL	13.0 to 1	0.0	"	"
3H	" " " " "	6WL	"	+6.0	"	"
4L	" " LINE NO.4	7WL	20.0 to 1	0.0	"	"
4H	" " " " "	8WL	"	+6.0	"	"



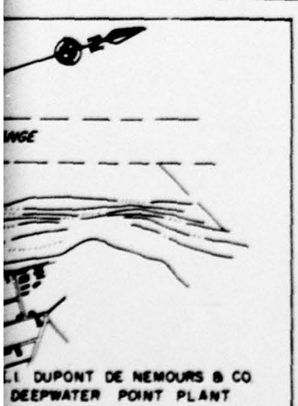
LOCATION PLAN

WESTINGHOUSE - LESTER

SCALE IN FEET

800 0 800 1600

FOR NOTES SEE PLATE 1



LONG RANGE SPOIL DISPOSAL STUDY

DESIGN OF DIKING IN WATER
DELAWARE RIVER BEACHES
LOCATION PLANS & GRADATION CURVES

U.S. ARMY ENGINEER DISTRICT PHILADELPHIA

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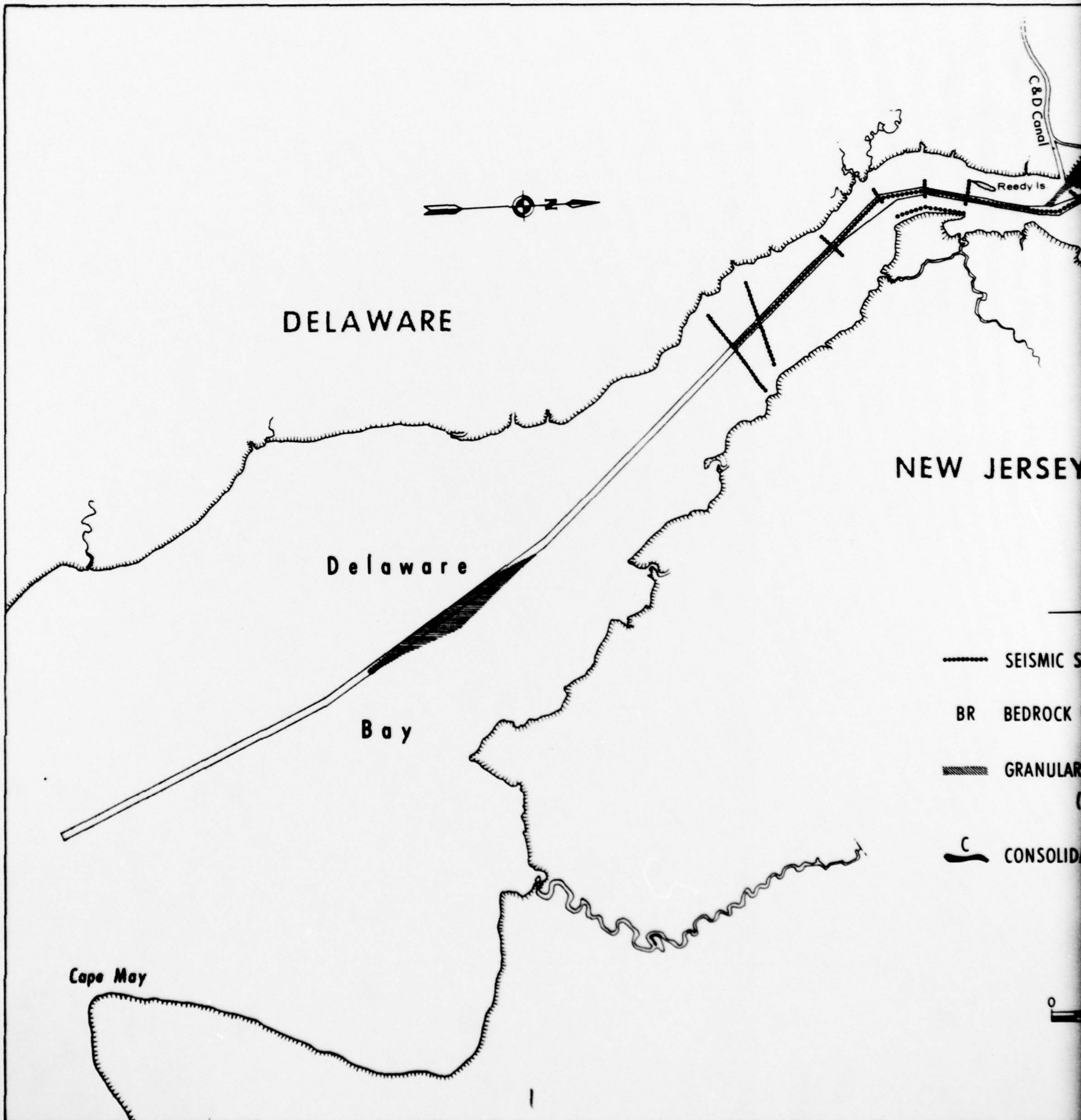
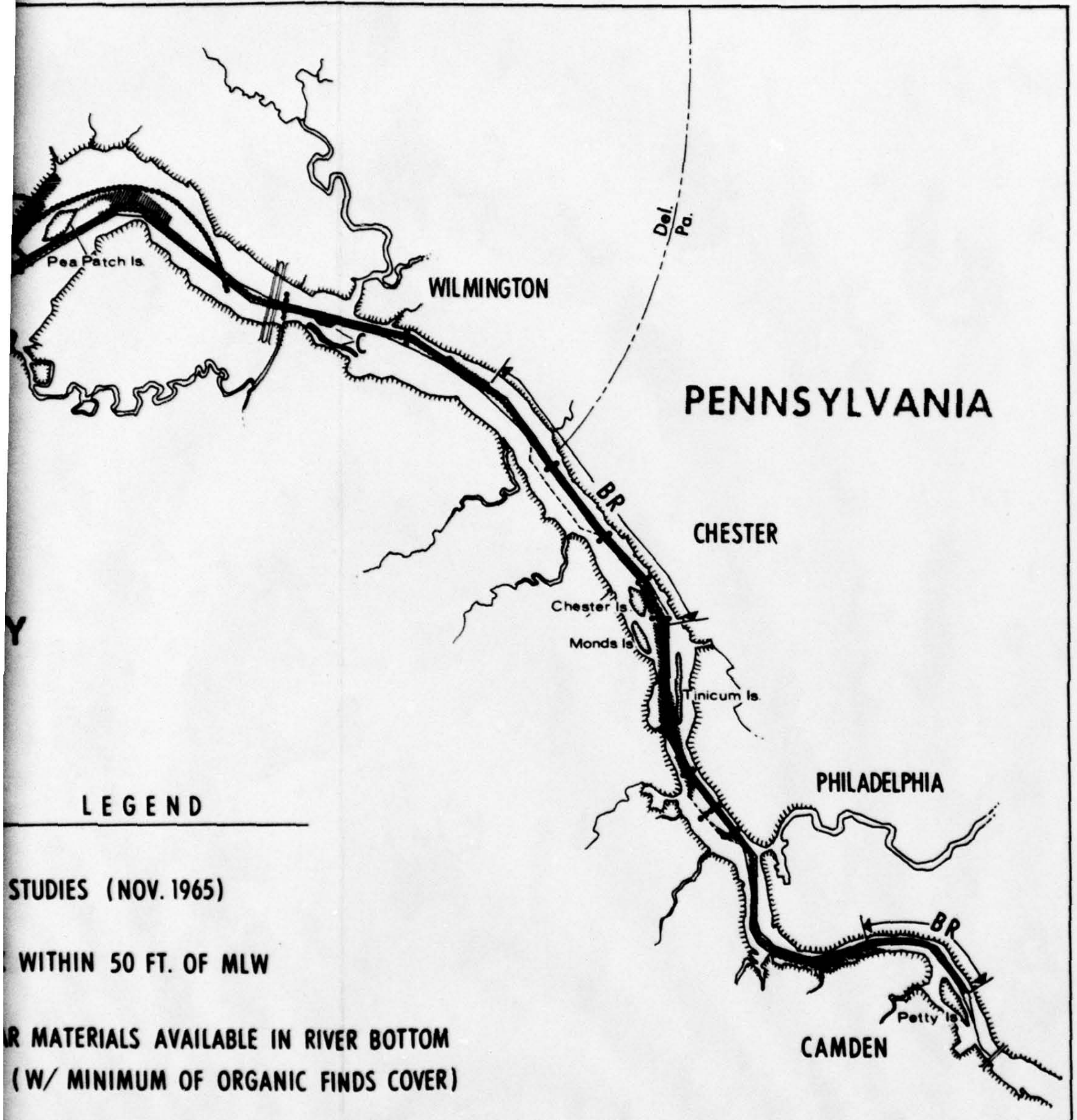


C&D Canal
Reedy Is
DELAWARE
NEW JERSEY
Delaware
Bay
Cape May
SEISMIC S
BR BEDROCK
GRANULAR
CONSOLID
C
0



LEGEND

STUDIES (NOV. 1965)

WITHIN 50 FT. OF MLW

AR MATERIALS AVAILABLE IN RIVER BOTTOM
(W/ MINIMUM OF ORGANIC FINDS COVER)

DATED, STIFF RED, WHITE & GRAY CLAYS
(CRETACEOUS RARITAN FORMATION)

Scale of Miles
5 10

LONG RANGE SPOIL DISPOSAL STUDY

RIPARIAN SOURCES
OF DIKING MATERIAL

U.S.ARMY ENGINEER DISTRICT
PHILADELPHIA